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Legacy of a Pest

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Illinois Natural History Survey

Special Publication 9

August 1988

Legacy of a Pest

A Science, Technology, and Society Curriculum Guide for Understanding and Dealing with Biological Problems

Laurie J. Case
Janet L. Wissmann
Michael R. Jeffords

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Introduction

The gypsy moth, an insect brought from Europe over a century ago, has become the most serious leaf-feeding forest pest in the eastern United States. The invasion of the Midwest by the gypsy moth poses a number of ecological and environmental questions that cannot be ignored.

The gypsy moth was introduced into Massachusetts in 1869 and since that time has defoliated millions of forested acres. Outside its established range, new infestations develop when egg masses are inadvertently transported to uninfested areas. Gypsy moth infestations have occurred in Illinois since the early 1970s. Although government agencies have managed to control these isolated populations, new infestations continue to appear. The battle against the gypsy moth is likely to prove chronic, and how this pest is managed is important to the citizens of Illinois. We have the opportunity to adopt environmentally sound strategies, and the adults who will help make those decisions in the future are today's schoolchildren.

The Illinois gypsy moth program was initiated in October of 1982 at the request of Governor James R. Thompson. It was preceded by the 1981 gypsy moth trapping survey, which captured 2,634 male moths in 84 communities in 13 Illinois counties. Most of the moths were caught in the Chicago area, but others were trapped at locations as far west as Rock Island and as far south as Salem. Because the female gypsy moth cannot fly, its transport to and dispersal within the state is due almost entirely to human activities. Historically, one of the greatest problems in dealing with gypsy moth infestations in the eastern United States has been a lack of public understanding of the gypsy moth and the control strategies used against it. In Illinois, we hope to avoid this problem through the development of a comprehensive educational program. This curriculum guide is a major component of that program.

Legacy of a Pest encourages students to explore a biological problem and its impact on society and the environment. It introduces the fascinating world of entomology, demonstrates why and how one insect (the gypsy moth) can have such a profound impact on the urban and natural forest environment, and suggests how the effects of the gypsy moth can be minimized through sound management practices. Further, the principles of thoughtful decision-making stressed in this package are applicable to a wide range of environmental, economic, and social problems.

Although our primary goal is to provide information about the gypsy moth, the more than fifty activities in this guide cover a broad range of topics including the abundance and diversity of insects, insect classification and identification, urban and natural forest ecology, and integrated pest management. We have tried to develop a holistic approach to the study of taxonomy, ecology, and pest management while using the gypsy moth as the demonstration organism. This strategy meets our goal of establishing an information base on the gypsy moth in Illinois and will, we hope, provide science educators throughout the state with useful classroom activities on entomology, ecology, and pest management.

We would like to thank Marilyn Sinclair, Science Coordinator, and Edee Wiziecki, Science Teacher, Columbia Middle School, Champaign, Illinois, for serving as technical consultants. Without their knowledge of and dedication to the development of curricular materials, this project would not have been possible. We thank members of the Illinois Natural History Survey staff for important contributions: Karen O'Hayer made creative suggestions for several activities, Molly Hardin Scott helped with the design and provided invaluable computer assistance, and Eva Steger helped with proof reading and compilation. We extend special thanks to Audrey Hodgins, Survey Technical Editor, for the arduous task of editing the manuscript. Finally, we are endebted to the following science teachers for fieldtesting portions of *Legacy of a Pest* in their classrooms: Sue Berg, Hawthorn Junior High School, Vernon Hills; Bob Burtch, J.B. Nelson School, Batavia; Marsha Gritton, Diamond Grade School, Danville; Jenny Grogg, University High School, Normal; Keith Hanson, North Ridge Middle School, Danville; Maureen S. Jamrock, Coolidge Junior High School, Phoenix; Charlene Koelling, Porta High School, Petersburg; Larry A. Kohn, Lake Park School, Addison; Doug Kuban, Pecatonica Grade School, Pecatonica; Don Nelson, Ridgewood School, Rock Island; Robert Smith, Prairie School, Urbana; Fredric H. Tarnow, Adams Junior High School, Schaumberg; Frances S. Vandervoort, Kenwood Academy, Chicago; Julia VanDyke, Urbana Junior High School, Urbana; Judy Williams, J.B. Nelson School, Batavia; Jackie Ziff, Leal School, Urbana. This project was supported by the Illinois Department of Energy and Natural Resources, Natural History Survey Division, Contract IP-2 (The Gypsy Moth Research and Education Program).

How to Use This Guide

Although *Legacy of a Pest* can be used independently, we have designed it primarily to supplement existing materials on insects and ecology. The activities were written for students in grades 5 through 10. Some are certainly more suitable for older students and others are clearly more appropriate for younger students, but most can be adapted for a wide range of grade levels. Teachers, of course, are the best judges of whether their students have the background to complete a given activity successfully.

Each of the twelve sections deals with a specific topic, as summarized below. Certain sections are of general interest, others deal specifically with the gypsy moth and explore the concept of integrated pest management. Each section begins with an introduction that clarifies the importance of the section and provides background information. Additional information can be found in references cited within activities or in the bibliography at the end of the guide. Sections can be used independently of each other; the only prerequisite is that students have the appropriate background to understand the concepts introduced.

The sections are briefly characterized as follows:

1. Insect Awareness: students become aware of the astonishing number and variety of insects in the world.
2. Definition of Insects: students examine insect anatomy and learn the unique characteristics of insects.
3. Insect Abundance: students are introduced to the reproductive potential of insects and learn to sample for insects in the field.
4. Food Webs: students become familiar with food webs, the trophic structure of communities, and the role of humans in the food web.
5. Taxonomy: students acquire and use scientific nomenclature, assemble an insect collection, and identify specific orders of insects.
6. Insect Development: students are introduced to the two types of insect development—simple and complete metamorphosis—and to the relationship between form and function in insects.
7. The Gypsy Moth: students become familiar with the history of the gypsy moth in the United States, study its life cycle and dispersal methods, and discover why it has become a major pest.
8. Gypsy Moth–Forest Interactions: students learn the food preferences of the gypsy moth caterpillar and the effect of the gypsy moth in the forest ecosystem.

9. The Urban Forest: students distinguish between urban and natural forests and learn the importance of diversity of species.
10. Pheromones and Detection: students learn how pheromones can be used to detect and trap gypsy moths.
11. Chemical, Cultural, and Biological Controls: students are introduced to various control methods used against insect pests, discover how resistance to pesticides develops and secondary pests emerge, and learn the importance of persistence and selectivity in pesticides.
12. Integrated Pest Management: students become familiar with the concept of integrated pest management and with the decision-making practices used in managing insect populations.

Each of the more than fifty activities that make up the twelve sections is listed in the table of contents. Each includes an instructional objective, the skills and processes emphasized in the activity, a list of materials needed to complete the activity, a detailed procedure for carrying out the activity, and a suggested evaluation. Vocabulary to be introduced and comments to the instructor are provided in some instances. Some activities rely on student handouts, and copies suitable for reproducing are included. A glossary of the vocabulary introduced in the activities is found at the end of the guide as is an appendix with instructions for constructing a sweep net, killing jars, and spreading boards.

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1. Insect Awareness: Background Information

After fighting off hordes of hungry mosquitoes, swatting at annoying house flies, and stepping on the ants walking through your kitchen, have you ever wondered how many insects there really are in the world? Insects and their relatives (arthropods) make up 78 percent of the known animal species. Scientists currently estimate that over one million species of insects exist. In contrast, only 5,000 species of mammals are found on our planet. These numbers mean that at least 200 insect species exist for every species of mammal. Indeed, over five times as many beetles live within the boundaries of the United States as mammals in the entire world.

An adult insect is defined as an air-breathing arthropod with a body divided into head, thorax, and abdomen. The head has one pair of antennae, and the thorax has three pairs of jointed legs. Adults often have one or two pairs of wings.

The scientific study of insects is known as entomology. As early as 322 B.C., Aristotle established the study of insect life. The Roman Pliny wrote the first volume of information devoted entirely to insects; however, it wasn't until the eighteenth century that de Reaumur laid the foundation of modern entomology. His six-volume work was the first well-illustrated classification of insects and included information on their behavior, ecology, and control.

Entomologists study insects for many reasons, but the incredible number of species and their wide variety of sizes, colors, shapes, and life styles interest us all.

1.A Observing Insects throughout the Year

OBJECTIVE to become aware of insects during all seasons of the year

SKILLS/PROCESSES observation, data collection and interpretation, analysis

An Activity for September

VOCABULARY germinate, infest, infestation, larva, larvae, pupa, pupae, pupate

MATERIALS

buckets or coffee cans
hand lens (10×) or dissecting microscope
flat jar lids or petri dishes
coffee filters or filter paper
flat-bottomed trays
nutcracker

COMMENTS In this activity students observe the acorn weevil. The female acorn weevil lays an egg in a small green acorn. As the acorn grows, the hole made when the female laid the egg heals over. In the fall the mature acorn falls to the ground, and the acorn weevil larva that has been feeding and growing inside the acorn chews its way out and burrows into the soil to pupate. It spends the winter months in the soil as a pupa and emerges the following spring to begin the cycle again.

larva

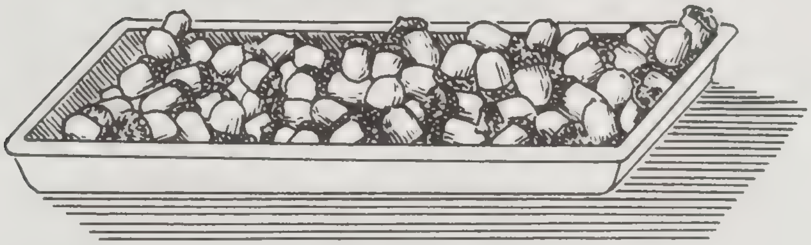
adult weevil
(3 times actual size)

PROCEDURE

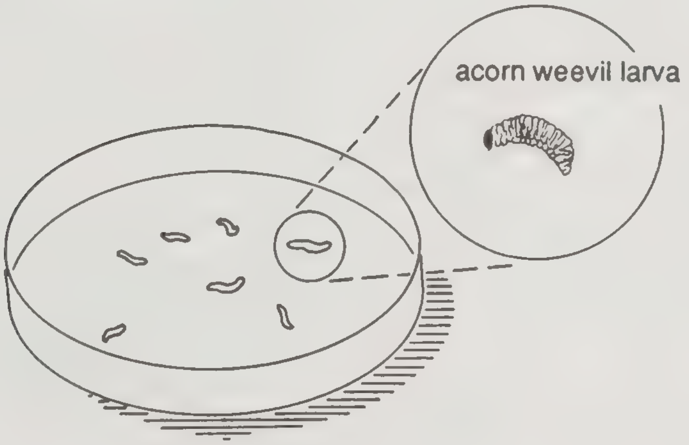
1. Scout the community in advance for oak trees producing large crops of acorns. When the acorns begin to drop (early to mid-September in Illinois), you or your students should collect them by the bucketful.

2. In the classroom, students look through the collection for acorns with small, round holes and record the number of acorns with holes and the number without. Together, compute the percentage of acorns infested with acorn weevils as indicated by the presence of holes. Then ask students to record the number of holes per acorn.

3. Place the acorns *without* holes in a flat-bottomed tray. Students examine these acorns daily for a week to note the appearance of holes. They also check the bottom of the tray for small, cream-colored acorn weevil larvae. When larvae are found, students place them in a jar lid or petri dish on a piece of filter paper lightly moistened with water.



4. Students observe the larvae with a hand lens or dissecting microscope and sketch them. Encourage detailed observation by asking questions such as these: Do the larvae have legs? How do you think they move around inside the acorn? What do their mouths look like? What effect do you think weevil damage will have on the germination of acorns?



5. At the end of the week, students record the number of larvae collected and recompute the percentage of infested acorns.

6. Open several acorns with holes to examine the damage done by acorn weevil larvae. Ask students to compare the interiors of these acorns to the interiors of uninfested acorns. (Acorns are usually unable to germinate if they have been infested with acorn weevils.)

EVALUATION

Students explain in a brief paragraph why the inside of an acorn is a good place for beetle larvae to live.

An Activity for Late Fall

VOCABULARY

decay, decomposition, humus, leaf litter

MATERIALS

clear plastic shoe or sweater box
lamp with a flexible neck

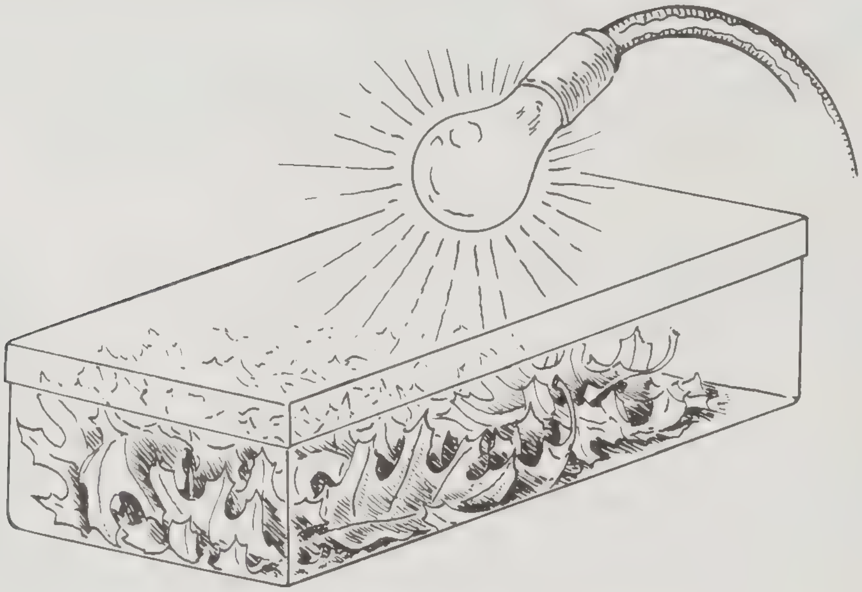
COMMENTS

Leaf litter, the loose material on the forest floor, is composed of plant materials in various stages of decomposition. The topmost layer is usually dry leaves; then comes a layer of moister, decaying leaves; and finally, moist decomposed leaf material called humus.

PROCEDURE

1. Collect leaf litter from a forested area and place it in the plastic box. Gather not only the dry leaves on the surface but also the moister material underneath.

2. Provide a source of heat and light by placing the lamp so that the bulb is near the top or side of the box. Students check daily for insect activity in the leaf litter. Why are insects now apparent when none were apparent earlier? What would have happened to these insects during the winter if we had not brought them indoors? Discard the materials after several days of observation.



EVALUATION

Students divide a sheet of paper into two columns, one labeled "change," the other "effect." Using this format, they explain how we changed the environment in which the insects lived and the effect on the insects of those changes. Share these responses.

A Second Activity for Late Fall

VOCABULARY

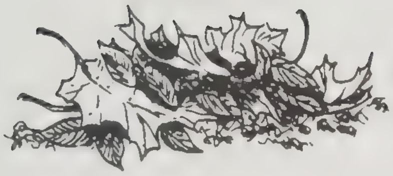
arthropods, Berlese funnel (burr-LAY-zee), community, decomposed, detritivores, dormant, ecosystem, entomologist, herbivores, leaf litter, organisms, parasites, predators

MATERIALS

1-gallon plastic milk jug
wide-mouth glass jar
hardware cloth (1/8" metal mesh screen)
white cloth (approx. 1 sq.ft.)
large rubber band
ethyl alcohol
lamp with a flexible neck or a droplight with a 60–75 watt bulb

COMMENTS

The Berlese funnel was named after the Italian entomologist Antonio Berlese of Florence. It is primarily used to collect arthropods from leaf litter and debris. Leaf litter, or soil litter, makes up the uppermost layers of the forest floor: dry leaves on top followed by wetter, partially decomposed leaves, followed by humus—a mixture of soil and rotten leaves. A typical Berlese sample from a midwestern woodlands contains many small arthropods and other organisms usually not seen. You may discover springtails, mites, spiders, pseudoscorpions, beetles, and many insect larvae of all descriptions.



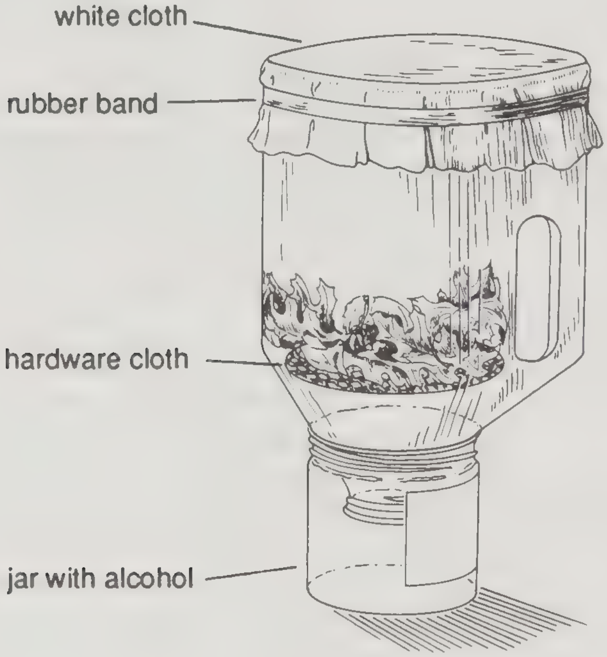
The layer of litter on the forest floor and the organisms that inhabit it make up a complex community in the forest ecosystem. The litter contains predators and parasites, herbivores (plant feeders) and detritivores (organisms that feed on dead and decaying matter). During the winter, many of these small animals simply remain in the litter, if it is thick enough, and become inactive or dormant. If the litter is thin, they may move to more protected sites deeper in the soil, to the bases of trees, or under logs and rocks. Even in the coldest months of winter, litter samples processed through a Berlese funnel yield a harvest of interesting creatures that have been awakened by warmth. If you collect leaf litter from a natural area (e.g., forest), you can expect to collect many more kinds of organisms than you would from litter in urban areas.

PROCEDURE

1. Collect a quantity of leaf litter from a forest or wooded area. Include the moist humus as well as dry leaves.

2. Wash and dry a 1-gallon plastic milk jug. Remove the bottom with a sharp knife or scissors. Invert the jug in the wide-mouth jar. Place a piece of hardware cloth in the neck of the jug.

3. Place 3–6 inches of leaf litter on top of the hardware cloth. Cover the large open end of the jug with the white cloth and secure it with the rubber band.



4. Carefully lift the jug—by now students should be referring to it as a Berlese funnel—and empty any soil debris that has fallen into the wide-mouth jar. Fill the jar with one inch of ethyl alcohol to capture and preserve organisms that fall into it from the litter. Reposition the Berlese funnel on the jar.

5. Place a 60–75 watt bulb about 6 inches from the top of the funnel. Leave the light on for at least 24 hours. As the heat from the bulb dries out the litter, organisms move down through the dry litter into areas with more moisture. Eventually they move through the hardware cloth and fall into the alcohol. After 24 hours, the jar will contain most of the organisms that were present in the leaf litter.

6. Conclude the activity with analytic and interpretive questions such as the following. How many different kinds of insects did we find? What other kinds of animals did we find? Group the animals that resemble one another. What group of animals was most abundant? What reasons can you give for the abundance of this type of animal?

EVALUATION

The vocabulary introduced in this activity is important here and later on. An appropriate evaluation for this activity is a brief quiz on the meaning and spelling of this terminology.

An Activity for Winter or Any Season

VOCABULARY

gall, galleries, larva, larvae, pupa, pupae

MATERIALS

multiple copies of **Signs of Insect Activity**

COMMENTS

Insects survive the winter in many different ways. Below is a list of some common insects and their method of surviving the winter.

Insect	**Stage in which winter is spent**	**Where winter is spent**
Grasshopper	egg	in the soil
Honey bee	adult	in a hive
Gypsy moth	egg	in an egg mass on a tree
Ladybird beetle	adult	under dead leaves
Firefly	larva	in the soil
Monarch butterfly	adult	in Mexico (migration)
Promethea moth	cocoon	hanging on branches
Acorn weevil	larva	in the soil

PROCEDURE

1. Conduct this activity in the school yard, a local park, an open field, a forested area, or along a railroad track.

2. Distribute and refer to **Signs of Insect Activity**. Students search for and list signs they believe are the result of insect activity: dead leaves with holes in them, tree bark with galleries, small holes in trunk bark, galls, pupae/cocoons on branches or twigs, insect homes such as tent caterpillar or wasp nests.

3. Discuss where insects go during the winter months. Are they alive? If so, how do they survive in cold weather? Discuss the stages in which insects may spend the winter—egg, larva, pupa, or adult—and the advantages or disadvantages of each for winter survival.

EVALUATION

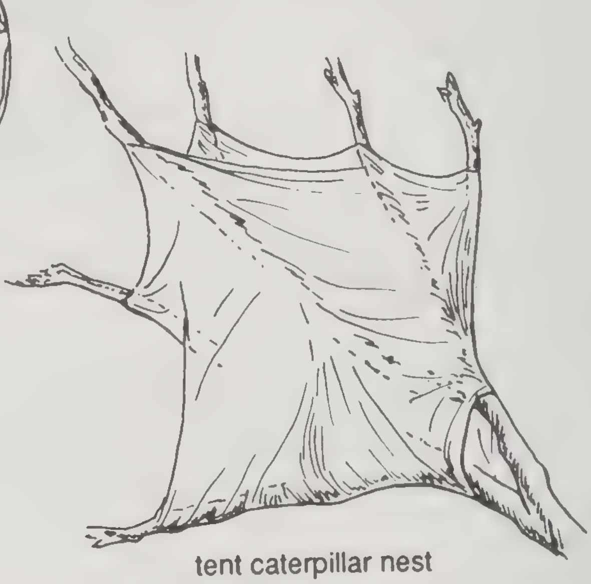
Compile with students at the chalkboard a list of common insects and the stage and place in which winter is spent.

Signs of Insect Activity

wasp nest

leaves eaten by insects

gall



tent caterpillar nest

beetle galleries

bagworm cocoon

acorn weevil holes

An Activity for Spring

VOCABULARY

data, habitat

MATERIALS

string marked off in 1-yard or 1-meter lengths
stakes, popsicle sticks, or twigs
multiple copies of **Observation Data Sheet**

PROCEDURE

1. Conduct the activity in the school yard, a local park, an open field, or a forested area.
2. Working in pairs or small groups, students use string and stakes to mark off a one-square-yard (meter) study area. Establish these areas in as many different habitats as possible so that a variety of data can be collected (a grassy area, a woody or shrubby area, the area adjacent to playground equipment).

3. Students examine their study areas carefully and complete an **Observation Data Sheet** for each area.
4. Discuss the findings together. Who found the largest number of insects and what were they doing? Who found the greatest variety of insects? Compare the plants and animals found in different habitats. Were some organisms found in all habitats or in only one habitat? What food would these various organisms eat?

EVALUATION

Have groups that studied different habitats compare their data. How are they similar? How are they different? What deductions can be made about each type of habitat? Share these observations as a class.

A Year-round Activity

MATERIALS

poster board or other light-weight card stock
glue or pins

PROCEDURE

1. On an ongoing basis and throughout the school year, encourage students to check areas such as the following for insects, alive or dead: windows and window sills, baseboard and ceiling corners, basements and garages, under bricks, boards, and stones, along the foundations of buildings and eaves, on trees and shrubs.
2. Maintain a list of places in which insects are found, including the numbers and kinds of insects for each site.
3. Glue or pin dead insects to sheets of cardboard, grouping together those that look alike. Identify each insect if possible, and affix a label that records name, collection date and site, and collector.

EVALUATION

The collection itself serves to evaluate this activity and to document increased student awareness of insects.

Observation Data Sheet

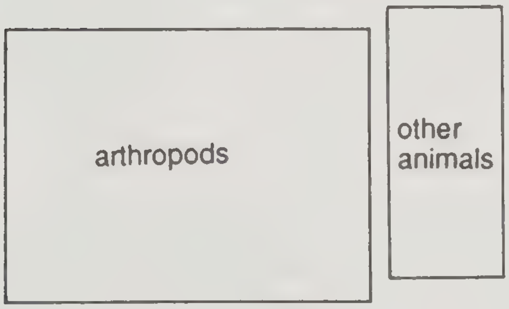
Name:

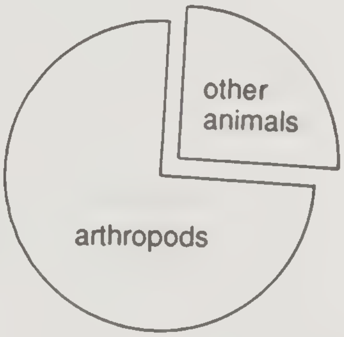
Directions: For items 1–4, circle the words that best describe your study area. You may circle more than one word. For items 5 and 6, enter the number of organisms found.

1. Ground cover	bare soil pavement lawn grass other plants		
2. Types of plants	weeds flowers bushes trees none		
3. Types of trees	large small trees with needles trees with leaves		
4. Signs of other animals	birds: droppings feathers nests	small mammals: droppings footprints hair	other animal signs: (list)
5. Number of insects	walking flying resting dead other forms of locomotion:		
6. Number of other animals	worms spiders snails others (list)		

1.B Number and Variety of Insects

OBJECTIVE	to become aware of the number and variety of insects
SKILLS /PROCESSES	comparison and generalization, grouping, fact finding, simple citation
VOCABULARY	arthropods, vertebrates
MATERIALS	multiple copies of **Insect Fact Sheet** magazines and newspapers scissors bulletin board posterboard tacks, stick pins, glue, yarn, string, crayons, etc.
COMMENTS	In spite of the difficulty students may have in finding insect pictures compared to pictures of other animals, insects are an integral and important part of the animal world. Insects are a major food source for most higher animals and some are important in the pollination of plants, including plants that provide our food. Activities 4.A and 4.C offer more information about the importance of insects in food webs.
PROCEDURE	1. Ask the class to cut pictures of insects from magazines and newspapers. Students may also trace pictures of insects from books. Together, prepare a bulletin board that is divided to indicate the relative number of insects versus the relative number of all other animals. Proportions may be approximated, but be sure that arthropods are allotted about three-fourths of the total area. If you prefer, students may work in small groups, each group completing a display on posterboard. Encourage various ways of constructing these displays: circles, squares, or rectangles; backgrounds of two contrasting colors; string or yarn dividers.





2. Ask students to paste or tack their pictures of insects in the arthropod section of the display, arranging them so that insects that look alike are grouped together.

3. Discuss the display, noting where a given insect might live or what it might eat. Focus attention on the many colors, shapes, and sizes of insects. Discuss questions like these: Did you have a difficult time finding insect pictures? What are the types of animals with which we are most familiar? Why are we not as familiar with insects? Does this mean that insects are not as important as other animals?

4. On a following day, ask students to cut from magazines pictures of all types of animals—including humans—and place them in the correct section of the display. Additional pictures of insects may be added to the arthropod section. Students will quickly discover that most pictures are of vertebrates and that these may not fit into their alloted percentage of the display.

5. Collect (with the help of the school or public librarian) an assortment of materials on insects: books, magazine articles, encyclopedia entries. Display these in the classroom or in a designated spot in the school library. Distribute the **Insect Fact Sheet** and discuss it as a group. Students then add facts to their sheets by consulting the resource materials. Put sample reference citations on the chalkboard so that students can correctly credit the references they used. Later, share these facts, perhaps by compiling a master fact sheet on the bulletin board.

EVALUATION

Students count off in threes, and each trio prepares a list of at least three new facts they have learned about insects. At least one of these facts must relate to insect numbers. Collect these lists for your evaluation or evaluate them as they are shared orally in class.

Insect Fact Sheet Name:

Asians cultivated the silkworm before 4700 B.C.

People of ancient Egypt raised honey bees. A honey bee hieroglyphic is inscribed on a sarcophagus dating back to 3633 B.C.

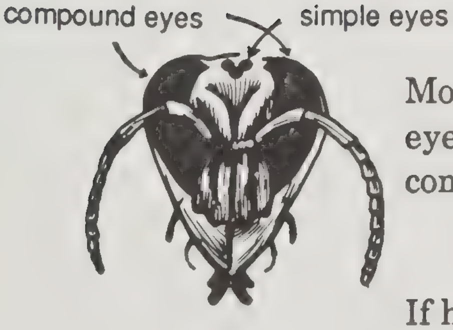
Scarab beetles (a type of dung beetle) were sacred to the Egyptians, who believed they symbolized eternal life. When an Egyptian died, his heart was removed and replaced by a Scarab beetle.

There are three times as many species of insects as there are species of all other animals combined.

A British entomologist estimated that 1,000,000,000,000,000,000 (a billion billion) insects are alive at every instant. Insects outnumber people by at least a million to one, and these million insects weigh 20 times as much as the human.

Estimates of the number of insect species vary from 1 to 10 million. No precise count can be made because the majority of insect species are unknown to science.

Insects range in size from about 1/100 of an inch to 13 inches in length and from 1/50 of an inch to nearly 1 foot in wingspread.



Most insects have two kinds of eyes: two or three simple eyes located on the upper part of the head and a pair of compound eyes on the side of the head.

If humans had the ability to kill all insects and were foolish enough to do so, the world as we know it would cease to exist. Humans would probably become extinct.

Definition of Insects: Background Information

The first reaction of most people upon seeing a crawling, creeping, or flying arthropod is to stomp, swat, or duck. Just what are we trying to avoid with these contortions? The creatures that provoke such responses are insects and their relatives, including spiders, millipedes, and mites. Even the smallest of these creatures that you often kill or avoid are remarkably designed and intricately structured animals. Down to the tiniest detail, their bodies are perfectly adapted for success on our planet.

An insect's body is composed of three main parts—the head, thorax (middle section), and abdomen. The head contains most of the sensory equipment such as eyes, antennae, and mouthparts. Mouthparts differ in size and shape depending upon their function. Some insects, for example, have piercing and sucking mouthparts for getting fluids out of plants or animals; other insects have chewing mouthparts for devouring prey or leaves; still others have sponging mouthparts for picking up fluids and other substances. The middle part of the body is the thorax. It houses the locomotor apparati—three pairs of legs and in many insects one or two pairs of wings. The abdomen contains the sexual organs used in mating and egg laying and the organs for digestion and breathing.

2.A Pretest: Insect Identification

OBJECTIVE	to record initial perceptions of what an insect is
SKILLS /PROCESSES	evaluation, generalization, identification
MATERIALS	multiple copies of **Pretest: Insect Identification**

PROCEDURE

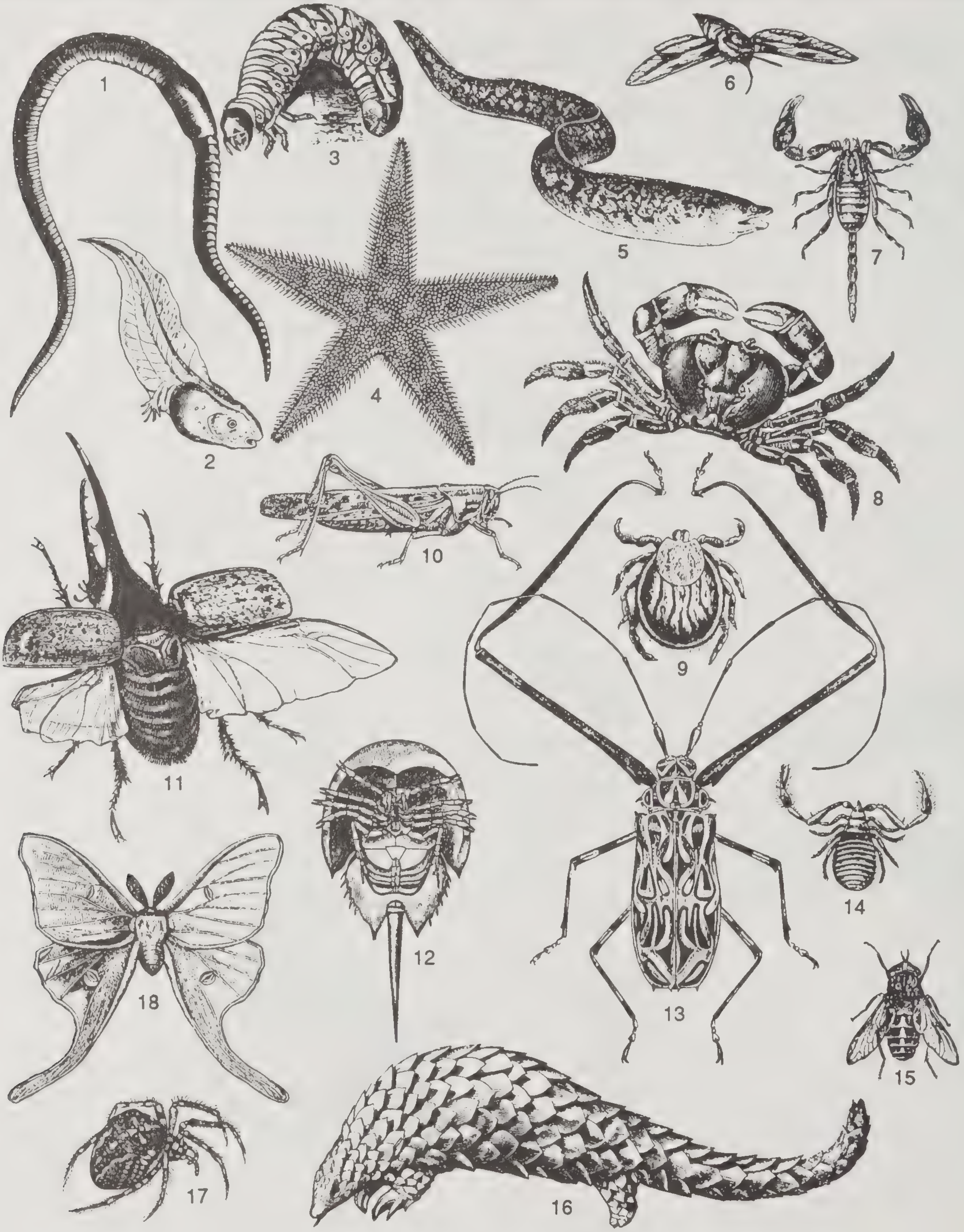
1. Distribute the pretest and ask each student to identify the eighteen animals by writing I (insect) or N (noninsect) in the appropriate blanks. The correct answers are given below. Although these papers should not be graded, students are usually curious to know whether or not they correctly identified the insects.

2. Collect the pretests and use them again later on after students have learned the definition of insect.

Pretest Answers

1. noninsect (earthworm)
2. noninsect (tadpole)
3. insect (white grub, larval stage of beetle)
4. noninsect (starfish)
5. noninsect (moray eel)
6. insect (sphinx moth)
7. noninsect (scorpion)
8. noninsect (crab)
9. noninsect (tick)
10. insect (grasshopper)
11. insect (unicorn beetle)
12. noninsect (horseshoe crab)
13. insect (harlequin beetle)
14. noninsect (pseudoscorpion)
15. insect (fly)
16. noninsect (pangolin)
17. noninsect (spider)
18. insect (luna moth)

Pretest: Insect Identification Name:



1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 ___ 7 ___ 8 ___ 9 ___

10 ___ 11 ___ 12 ___ 13 ___ 14 ___ 15 ___ 16 ___ 17 ___ 18 ___

2.B Biological Definition and Anatomy

OBJECTIVE — to learn the biological definition of an insect and to understand basic insect anatomy

SKILLS /PROCESSES — computation, description, generalization, invention, observation

VOCABULARY — abdomen, antenna, antennae, compound eye, thorax

MATERIALS
drawing paper
crayons or colored pencils
colored chalk

COMMENTS

Although not all insects fit the definition given below, the majority do. An adult insect is composed of three major body parts:
Head, with one pair of antennae and one pair of compound eyes (a compound eye is composed of many small eyes).
Thorax (the middle part), with three pairs of legs attached on the underside and one or two pairs of wings attached on the top.
Abdomen (the rear part); no legs or wings found here.

PROCEDURE

1. Ask each student to draw an adult insect and label it "before." Give no prior information about the body parts of insects.

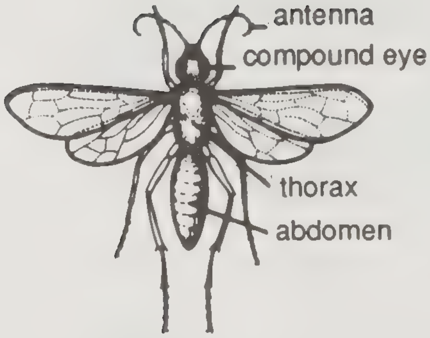
2. Divide the class into groups of five or six students and assign a number to each group. A volunteer from each group tallies the following information about the drawings made by his or her group:

group no.	student names					
	Joe	Sue	Bill	etc.		group total
number of heads	1	1	1		=	
number of legs	4	6	4		=	
number of wings	2	2	4		=	
number of eyes	2	2	4		=	
number of antennae	2	0	0		=	
other parts:						
nose	1				=	
etc.						

3. After each group has calculated its total, make a class tally on the chalkboard:

class tally	group number 1	2	3	etc.	class total	divide by class size	average
number of heads		+	+		=		=
number of legs		+	+		=		=
number of wings		+	+		=		=
number of eyes		+	+		=		=
number of antennae		+	+		=		=
other parts:							
					=		=

For each row—"Number of legs," for example—combine the group totals to obtain a class total. Divide that total by the number of students in the class to obtain the average number of legs drawn by students. Repeat for each row of data, rounding fractions to the nearest whole number.



4. Ask for a volunteer to draw the "class insect" on the chalkboard. Take a vote to determine its basic shape (oval, round, triangular, square, irregular). If a student suggests that the body should be made up of two parts—thorax and abdomen—Bravo! The volunteer then adds to the body the average number of heads from the class tally. Complete the drawing by adding the average number of legs, wings, eyes, and antennae. The class may enjoy giving the volunteer specific directions regarding how these body parts are to be drawn.

5. The finished drawing may not resemble an insect, but now is the time to introduce the definition of an adult insect given in the comments above. Although not all insects fit this definition, the majority do. As you introduce the three parts and their components, ask a volunteer to adjust the drawing on the chalkboard accordingly.

EVALUATION

Students describe briefly in writing how they would change their "before" drawings. Each student then makes a new insect drawing, labeling it "after." If you wish, before and after drawings may be paired on the bulletin board.

2.C Close-up on Crickets

OBJECTIVE

to take a close-up view of external insect anatomy

SKILLS /PROCESSES

observation and comparison

COMMENTS

Because the vocabulary is particularly important in this activity, a list has been prepared for photocopying. You may wish to incorporate these words into a spelling or other language arts activity.

MATERIALS

crickets (from a pet or bait store), one for each student
multiple copies of **Cricket Lab Report 1–5** and **Cricket Vocabulary**
70% alcohol or access to a freezer
10× hand lens or dissecting microscope
dissection pans or paper towels
dissecting needles or straight pins
tweezers
sharp, fine scissors

PROCEDURE

1. Kill the crickets by placing them in alcohol or in a freezer for several hours. Keep them frozen or in alcohol until just prior to the activity. As an option, you may wish students to observe the live crickets and to record their activities: walking, hopping, cleaning their antennae, chirping.

2. Give each student a cricket and a copy of **Cricket Lab Report.** Depending on the age and lab experience of your students, they may work independently by following the guide or by attending to your explanations and then following your example.

3. When students have completed the lab report, discuss the answers they provided and questions they may have. You may wish to collect the reports for a more formal evaluation.

4. As a subsequent activity, use the vocabulary sheet to reinforce the terms introduced in the lab report. Students should insert written definitions for these terms without resorting to a dictionary. You may also wish them to prepare for a spelling quiz on the cricket vocabulary.

EVALUATION

1. Ask the class to count off in twos. At least three pairs should work at the chalkboard. Ask each pair to draw an insect showing head, thorax, abdomen, legs, wings, compound eyes, and antennae. These parts should also be labeled. Compare and discuss the drawings at the chalkboard, correcting any inaccuracies in body parts or spelling. Encourage students to use the vocabulary introduced with this lesson (ventral, dorsal, posterior, anterior, etc.) in this discussion.

2. Prepare in advance strips of paper about 3" × 11". You will also need a felt-tipped marker and transparent tape. Ask students to name as many parts of an insect as they can recall. As they name these, print each one with the marker on one of the paper strips. Add any they may have forgotten, including anterior, posterior, ventral, dorsal, femur, etc. Ask for a volunteer "insect," preferably one who is wearing blue jeans. Distribute the slips of paper at random to members of the class. Each student in turn defines the word he or she received and then tapes it in place on the human insect. Allow for some innovative placements—the nose for spiracles or the hands for antennae— but ask students to justify these.

Cricket Lab Report 1 Name:

Introduction

The cricket is a very familiar insect. It is a member of an order of insects called Orthoptera (or-THOP-terr-uh). Other insects in this order include grasshoppers and katydids. Most of these insects are plant feeders and a few are predators.

grasshopper

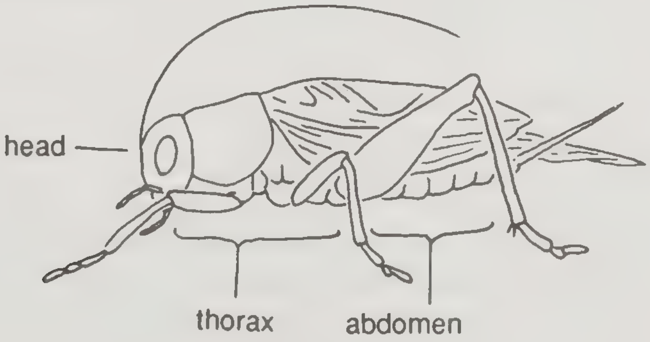
katydid

We often hear the male cricket chirping to attract mates during the warm nights of summer. The songs the crickets sing are made by a process called **stridulation** (strid-yu-LAY-shun). The cricket stridulates by rubbing a sharp edge (the scraper) found at the base of one front wing along a filelike ridge (the file) on the underside of the other front wing. Only the males sing. The rate at which a cricket sings depends on the temperature. The higher the temperature, the faster he chirps.

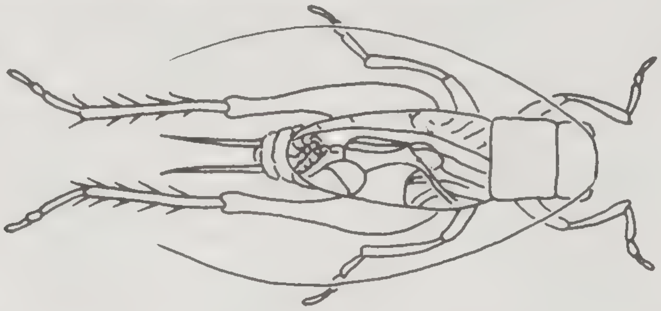
1. Look at your cricket and notice that it is **bilaterally symmetrical**; that is, if you drew a line down the center of the cricket, from its head (**anterior** end) down its back to the tip of its abdomen (**posterior** end), both sides would look alike. People are bilaterally symmetrical, too. Can you think of other animals that are bilaterally symmetrical? List two examples below.

a.____________________ b.____________________

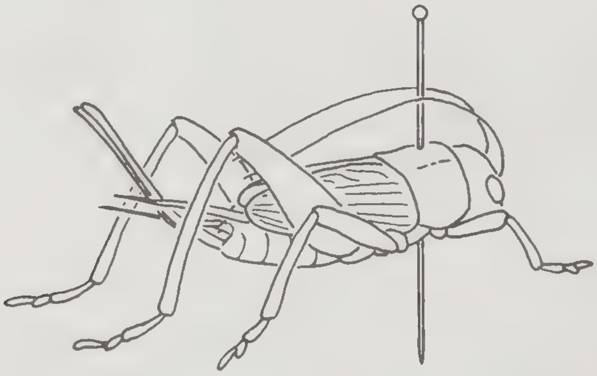
2. The cricket's body is composed of three parts: the **head**, the **thorax**, and the **abdomen**. Find each part on your cricket.



3. Put your cricket in the dissecting pan or on paper towels with its back facing up, towards you. When you look down at the cricket, you are seeing its top or **dorsal** side. The part you can't see—its underside—is called the **ventral** side.



4. Attach the cricket to the dish or paper towel by putting a pin through its thorax as shown below. Label the dorsal and ventral sides of the cricket below.



Examining the Head

1. With your hand lens or under the low power of the dissecting microscope, examine the head closely. List three functions performed by the head.

a.____

b.____

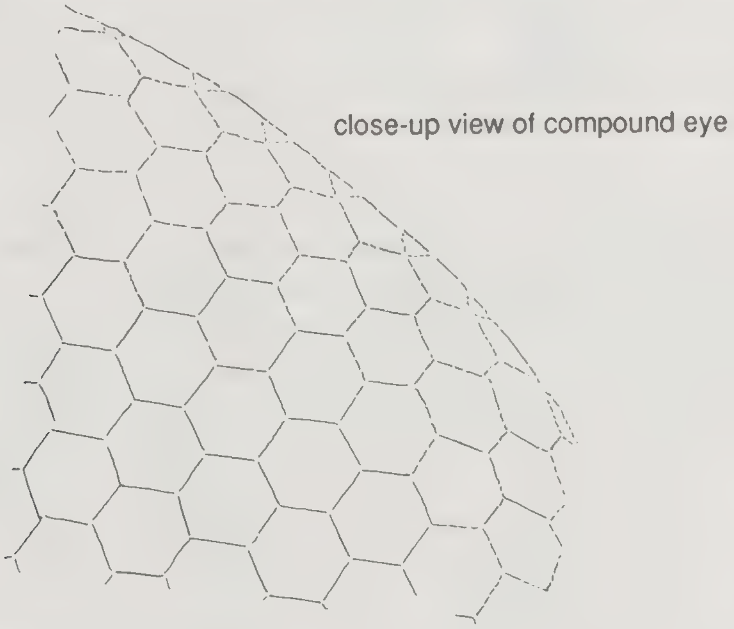
c.____

In the space below, draw the head of your cricket.

2. The large, paired, jawlike parts of the mouth with the rough-looking edges are the **mandibles**. The mandibles move sideways and bite off and chew particles of food. Use a straight pin to move the mandibles sideways. Label the mandibles on your drawing.

3. Examine the **antennae** (an-TEN-nee) and label them on your drawing. Antennae are used by insects to touch and feel things they find in their habitat. Antennae are also used to smell things in the environment. The singular of antennae is **antenna**.

4. Using the hand lens or the dissecting microscope, look at one of the large eyes of the cricket. It is a **compound eye**. Each small, six-sided area is called a **facet**. A compound eye is made up of many facets. Each facet acts like a small eye and passes light through to a nerve. The nerve passes this information on to the brain. In the brain, all the information sent by the many facets forms a picture. Label a facet in the drawing below. Then go back and label the compound eye in your drawing of the cricket's head.



Examining the Thorax

1. Study the thorax of the cricket. Then list two jobs it performs.

a.____________________________________

b.____________________________________

2. The six legs and the wings are attached to the **thorax**, the **locomotor center** of the insect. Three segments make up the thorax: front, middle, and back. Move the cricket from side to side in order to see the three segments.

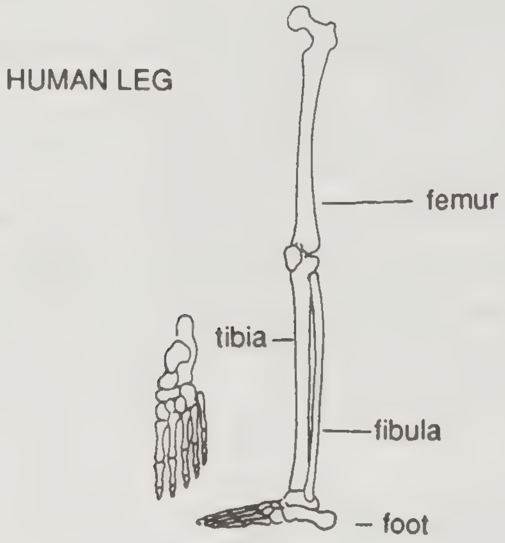
a. To which segment(s) of the thorax are the legs attached? __________________

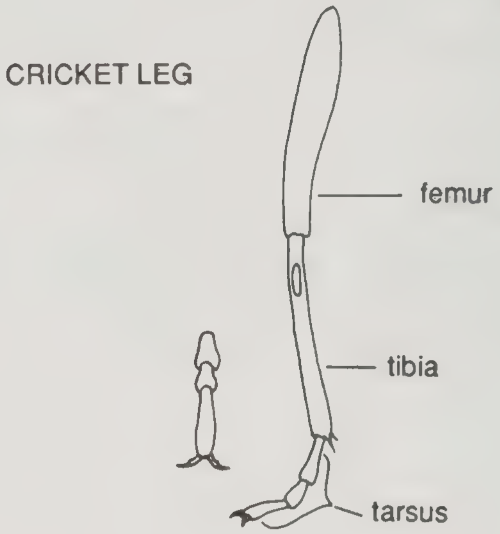
b. To which segment(s) of the thorax are the wings attached? __________________

Cricket Lab Report 4 Name:

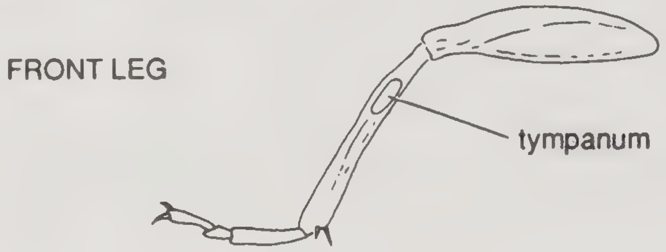
3. Look at the front legs of your cricket. Compare the two pictures below. What two parts of the human leg and insect leg are similar?

______________ and ______________





4. At the base of the tibia on the front legs, you can see the cricket's ear. It is called the **tympanum** (tim-PAN-um) and resembles your eardrum.



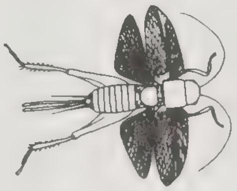
5. Draw a picture of the back leg of the cricket below. Note the large, upper part of the back leg—the **femur** (FEE-mer). Label it on your drawing.

What do you think the job of the back leg is? ______________________

Cricket Lab Report 5 Name:

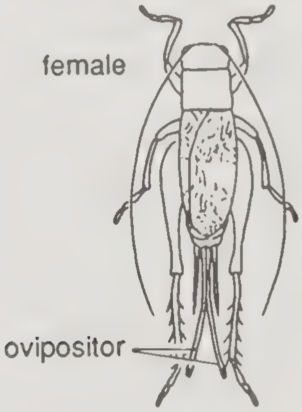
Examining the Abdomen

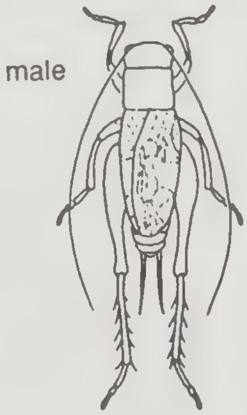
1. Spread the wings covering the abdomen as shown below. Pin them out of the way or cut them off with scissors. Examine the abdomen.
Name one job you think it performs. ________________________________



Draw the abdomen of your cricket from the **dorsal** side in the space below.

2. The female cricket has a long, needlelike structure on the end of its abdomen. This structure is called an **ovipositor** (oh-vi-POS-i-ter), and the female cricket uses it to lay eggs. The male cricket does not have an ovipositor, but it has a smaller structure on the end of its abdomen which it uses when mating.





Is your cricket a male or female? ____________

3. Move the abdomen to find out if it bends or if it is stiff. Look on the sides of the abdomen for small circular holes. These are called **spiracles** (SPEAR-i-kuls) and the insect breathes through them. Label the spiracles on your drawing of the abdomen.

Cricket Vocabulary Name:

abdomen

antenna

anterior

bilateral symmetry

compound eye

dorsal

facet

femur

locomotion

mandible

posterior

spiracles

stridulation

thorax

tibia

tympanum

ventral

2.D External Anatomy

OBJECTIVE

to understand more fully the external anatomical features of insects

SKILLS/PROCESSES

application, creativity, group planning, transfer of previous learning

MATERIALS

balloons
wire and wire cutters
newspaper torn into strips
flour paste
tempera paints, colored tissue paper, construction paper
pipe cleaners, sequins, and other decorative materials

COMMENTS

Teachers who have no experience with papier-mâché and wire sculpture may want to consult with an experienced colleague or with an art teacher. Craft books from the library will also help. Note: As an alternative to papier-mâché craftmaking, you may use the written activity described in the option below.

PROCEDURE

1. Divide the class into groups of three or four students. Each group will design and construct an insect that conforms to the biological definition. Before beginning construction, however, each group should decide what type of food this insect eats and the habitat in which it will live: on grass, on flowers, in or on trees, in or on the water, on dogs and cats, in open fields. How does the insect move? How does it protect itself? The answers to these questions (food, locomotion, habitat, protection) should be answered on a sheet of paper before construction begins. The group then decides what adaptations their insect will have in order to increase its chances for survival. Students may copy the form of an existing insect or create an entirely new species with an appropriate name.

2. The wire can be used to sculpt insects to which tissue paper wings can be added. It can also serve to provide a structure on which papier-mâché bodies can be built. Inflated balloons can also be used for this purpose. Tissue paper can be used to create wings supported by frames made from wire or from construction paper. Papier-mâché bodies can be painted with tempera or covered with flour paste and strips of colored tissue.

3. Display the insect creations and ask students to vote for favorites in categories that they have defined: most beautiful, most likely to get stepped on, most efficient feeder, most likely to survive. This project can be expanded by arranging a contest between other classes and other teachers. You may want to invite an extension advisor, area naturalist, pest-control agent, or other insect expert to judge the creations. In lieu of a contest, you can make an attractive display of the insects by suspending them from ceiling light fixtures or from cords strung across the room.

OPTION

1. Divide the class into groups of three or four students. Each group will design, draw, and color an insect that conforms to the biological definition. Before drawing the insect, however, each group should answer the following questions on a sheet of paper.

a. Food	What does your insect eat?
b. Locomotion	How does your insect get around?
c. Habitat	Where does your insect live?
d. Protection	How does your insect protect itself?

2. Each insect drawn by the students should have insect characteristics: three body parts, six legs, two or four wings, antennae. The insects should be colored appropriately, depending on the answers to a–d above.

3. Each group names its insect and then writes a description of it.

EVALUATION

Each group of students devises a simple score card and uses it to rate the general anatomical accuracy of the insects created by at least five other groups. Later, compare the items students chose to include on their score cards and how the same insects were rated by various groups.

3. Insect Abundance: Background Information

The fossil record indicates that insects have inhabited the earth for around 350 million years. In fact, ancient humans were probably harassed by blood-sucking insects just as we are today. Very likely they also used such insects as caterpillars, grubs, and grasshoppers as food. Insects remain important today because we depend on them to pollinate our food crops; we also spend billions of dollars trying to control those we consider pests.

How many insects are there? The exact number of species is unknown because areas of the world remain to be studied by entomologists. Nevertheless, they are abundant with an estimate of over *one million* living species. Over a quarter of a million species of beetles have been described, and 28,600 of those are found in the United States.

Why have insects proved so successful? One reason is their small size, which lets them occupy habitats too small for other animals. In addition, their small size allows them to survive and reproduce on small amounts of food. Another reason for their success is their short life cycle. An insect can utilize habitats or food resources that are available for only a short time. The success of insects also depends upon their ability to move from unfavorable sites to more favorable sites, often by flying. In addition, insects have a large potential for reproduction: one female gypsy moth, for example, can lay 1000 eggs; a queen bee can lay 2000 eggs a day, 365 days a year, for many years. With these adaptations for survival and reproduction, insects are assured a prominent place on the Earth of the future.

3.A Sampling

OBJECTIVE

to discover through sampling the abundance of insects

SKILLS/PROCESSES

mapping, data collection and interpretation, calculation

VOCABULARY

density, inventory (verb and noun), sample (verb and noun)

MATERIALS

graph paper and pencils
string cut into 3-meter lengths
stakes or popsicle sticks
jars with lids for specimens collected
multiple copies of **Data Sheet: Outdoor Sample Plot**
clipboards are useful, one for every three or four students

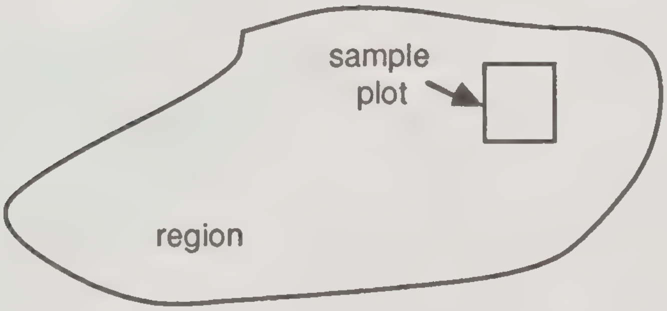
COMMENT

In order to study the ecology of an area, scientists need to know what organisms are present and in what numbers. In most areas, an exact count of every member of every species is impractical if not impossible. Instead, scientists closely study one or more small sample plots within a larger region. They then use the data collected from these plots to estimate population sizes in the region.

A sample plot must be highly similar to the larger region. If, for example, the region you want to study is a mowed grassy area, you must choose a sample plot that is also a mowed grassy area. If the sample plot you choose has trees on it, then it is representative only of that part of the larger region that is wooded.

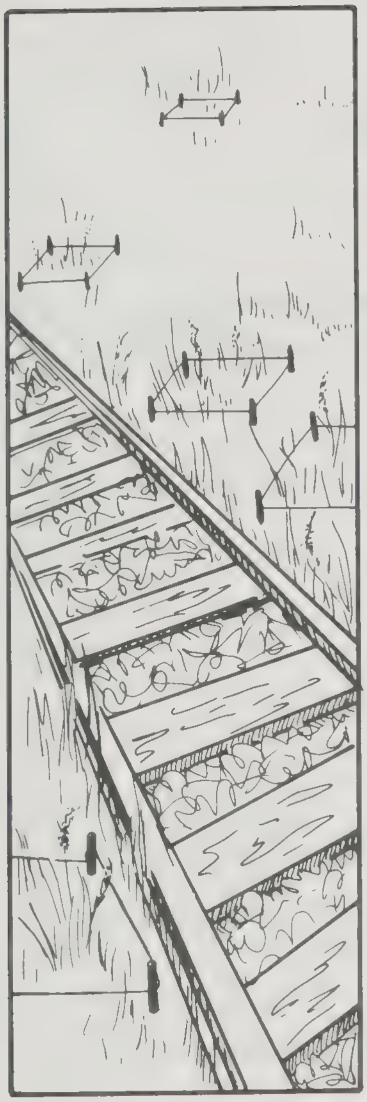
PROCEDURE

1. Explain the idea of **sampling** to your class. Use a simple drawing such as the one below to illustrate representative samples.



2. Take the class to a weedy lot, a grassy roadside, a weedy railroad border, or a grassy area of the school yard.

3. Divide the class into teams of three or four students and give each team a copy of the data sheet.



4. Measure or estimate (pacing off is adequate) the dimensions of the region in which the class is working. Be sure to include only areas of similar habitat in your estimation of region size. Each team records this information on its data sheet.

5. Using stakes and 3-meter lengths of string, each team stakes out a plot 3 meters by 3 meters. Make sure that the plots are scattered and all are in the same type of habitat as the region measured in Step 4. Using graph paper, each team draws a map of its plot to scale. Such landmarks as fallen logs, rocks, railroad ties, and trees should be indicated.

6. Each team inventories all insects found in its sample plot and records this information on its data sheet. Students should bring back to the classroom a sample of any insect not identified in the field. Be sure that students record the number of each kind of insect. Insect colonies such as anthills should be noted on the data sheet; later their population will be estimated in the classroom. A time limit of about 15 minutes may be set.

7. Back in the classroom, each team completes items **a** through **e** on the **Data Sheet**. Students who found anthills should multiply the number of anthills by 5,000. Ant colonies range in size from 100 to 20 million ants. Average colony size for North American species is 5,000. To compute the density of insects (number per square meter), students divide the total number of insects in the plot by the area of the plot in square meters (item **e**).

8. Finally, each team estimates the number of insects in the entire region (item **f**).

9. Discuss questions such as the following: Which team had the highest density of insects in its sample plot? the lowest? What might explain these differences? (If students suggest that different teams used different methods, discuss these variables. Did, for example, one team scare insects out of its plot before they began counting?) Which team found the greatest variety of insects? the least variety? What might explain these differences? Can an insect spend its entire life on a sample plot? (A caterpillar probably could live its whole life within the area of the plot. A gypsy moth from egg to caterpillar to pupa spends its entire life on the same tree. The caterpillar of a black swallowtail butterfly grows to adulthood on a single carrot plant!)

EVALUATION

Devise with the class a plan for determining the approximate number of pigeons or sparrows that live in your city. If you prefer, ask each team to write a plan for accomplishing this task. Then compare plans and formulate a master plan that incorporates the best ideas.

Data Sheet: Outdoor Sample Plot   Name:

Measured or estimated dimension of entire region = ____ meters × ____ meters

Dimension of sample plot = ____ meters × ____ meters

Record on the lines below each kind of insect you find (crickets, ants, ladybugs, grasshoppers, mosquitoes, etc.) and the number of each. If you cannot identify an insect, place it in a collection jar. Assign that insect a letter and use that letter to complete this Data Sheet.

Kinds of Insects	Number of Individuals of Each Kind

Number of anthills ______________________

a. Total kinds of insects ____

b. Total number of all kinds of insects ____

c. Area of sample plot ____ square meters

d. Area of entire region ____ square meters

e. Density of insects in your sample plot ____ insects per square meter

f. Estimated number of insects in the entire region = d × e = ____

3.B Reproductive Potential

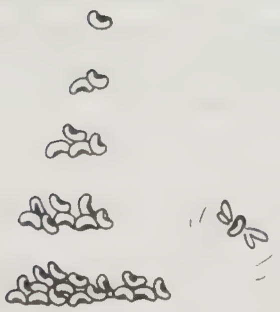
OBJECTIVE	to conceptualize the enormous reproductive potential of insects and to understand why the world is not covered with insects
SKILLS/PROCESSES	calculation, data interpretation, inference
VOCABULARY	generation, offspring, reproduction, reproductive potential
MATERIALS	graph paper and pencils 3–5 pounds of dry beans or 2 pounds of rice several containers into which you have divided the beans—"bean banks" paper plates
COMMENTS	The reproductive capability of insects is staggering. One female aphid, for example, could be responsible at the end of a single summer for the production of 1,560,000,000,000,000,000,000,000 aphids—her "children," "grandchildren," "great-grandchildren," etc. Not all insect eggs and young survive, however, because diseases kill them and other insects and birds eat them. You will need a working definition of generation—the time required for an adult animal to produce offspring and for those offspring to grow to be adults.

PROCEDURE

1. Divide the class into groups of four or five students. Assign the name "Doublers" to half the groups and the name "Triplers" to the others. Place the "bean banks"—the containers holding the beans—at locations convenient to the groups.

2. Explain the following directions to the entire class.

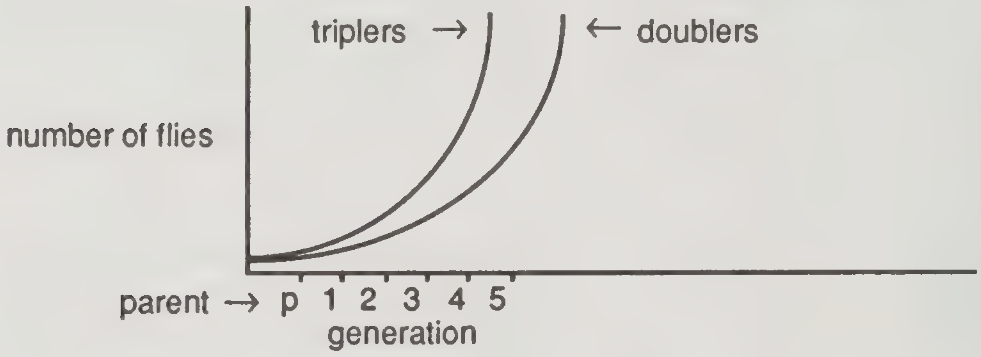
   Directions for Doublers: Suppose that at the beginning of summer a female fly lays two eggs that grow into female flies. Then the female fly dies. About two weeks later, the two new females each lay two more eggs that grow into female flies. This goes on for five generations. How many flies will be present at the end of five generations? Each group of doublers places one bean on a paper plate to represent the original female parent. Doublers then add two beans to the plate and remove the parent to represent the first generation of flies. For the second generation, they add two more beans for each parent bean on the plate and remove the parents. For the third generation, they add two more beans for each parent on the plate and remove the parents. They continue this process for each generation, writing down the numbers of beans on the plate after each generation as shown below. Allow a minute or two before you announce the birth of the next generation.



Directions for Triplers: Triplers follow the same scenario presented to the Doublers except that each adult fly now lays three eggs. Triplers keep track of their totals as did Doublers.

generation	Doublers: number of female flies	Triplers: number of female flies
parent	1	1
1	2	3
2	4	9
3	8	27
4	16	81
5	32	243

3. Each group plots its results on graph paper. Ask for a volunteer Doubler and Tripler to graph their results on the chalkboard. Graphs should resemble the example shown below.



4. Discuss the results. Compare the numbers of flies produced when each female lays only 2 eggs with the numbers produced when each female lays 3 eggs. Actually, an adult female fly can lay more than 200 eggs. After five generations, there would be more than 10,000,000,000 or 10 billion flies! All these flies come from just one female at the beginning of summer. If placed end to end, the string of flies would be 40,000 miles long.

5. Obviously not all flies live to reproduce. List with the class possible ways that flies die. If students know the life cycle of a fly (egg, larva or maggot, pupa, and adult), categorize this list by life stage. Apart from the obvious death of flies at the hands of humans, a fly can die from a myriad of causes. In the egg stage, flies are vulnerable to drought, raiding ants, fungus, and parasites that lay their eggs inside a fly egg. As larvae, too, flies are susceptible to drought; if their food supply dries out, the larva may also dry out and die. As larvae, they can be eaten by birds, mice, and other insects. Some parasitic wasps lay eggs in fly larvae and consume the larva's internal organs. Fungus, bacteria, and even competition for food by other insects also take their toll of fly larvae. Adults are eaten by birds and fall victim to many diseases as well as to fungal infections.

EVALUATION

Ask each student to find an original way to show the reproductive capabilities of insects: bar graph, poster, three-dimensional display made with beans or rice or with stick pins, map pins, or thumb tacks. Some students may elect to make a poster comparing five human generations with five insect generations.

Food Webs: Background Information

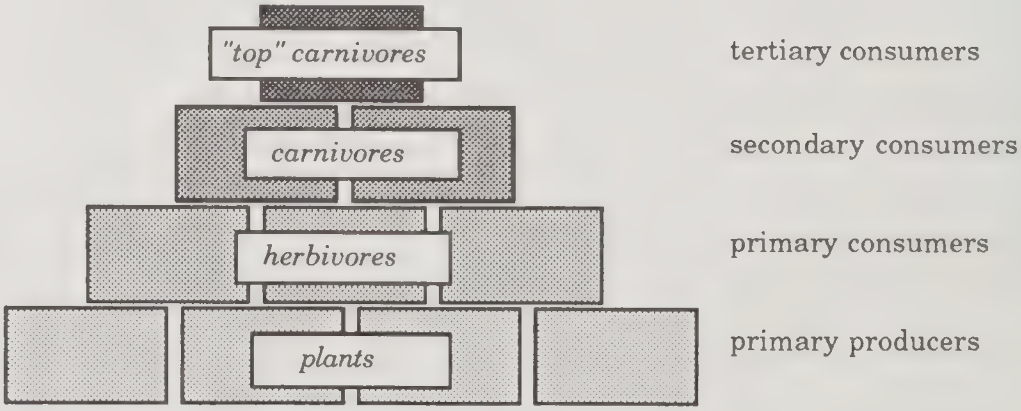
When scientists study the structure and functioning of food webs, they use a specific vocabulary to describe the relationships observed between various organisms. A term often used in the study of food webs is **trophic**. The dictionary defines "trophic" as "having to do with nutrition." Trophic structure, then, is the nutritional interrelationships between organisms in a particular food web. A simple method for understanding the trophic structure is to envision a pyramid composed of several layers where each layer is dependent upon those supporting it. Each layer in the pyramid is a **trophic level**.

Plants compose the base or bottom trophic level of the pyramid. They absorb the energy of sunlight and convert it into growth. Plants, therefore, are called **primary producers**. In the trophic pyramid, organisms in the layer just above the primary producers are called **primary consumers**. Not only do they consume food from the layer below them, but they also *are* food (or producers) for the layer above them. These primary consumers feed on plants and are called **herbivores**. The next level in the pyramid consists of **carnivores**. Carnivores feed on other animals and are called **secondary consumers** because they feed on the primary consumers, herbivores. There may be several layers of carnivores in a particular food pyramid, since carnivores may feed upon other carnivores. All trophic pyramids, however, come to a point with a few "top" carnivores.

Some animals—omnivores—eat both plants and animals from various trophic levels. These types of animals change the structure of the pyramid. The layers are no longer separate and distinct but form a complicated structure called a **food web**.

Where do insects fit into food webs? Almost everywhere above the primary producer level! The roles they play are crucial to the proper functioning of the food web. Insects feed on a wide variety of plants, help decompose dead organisms, and aid in the pollination of plants. Insects also are major food resources for other organisms such as birds, amphibians, mammals, and even other insects.

TROPHIC STRUCTURE

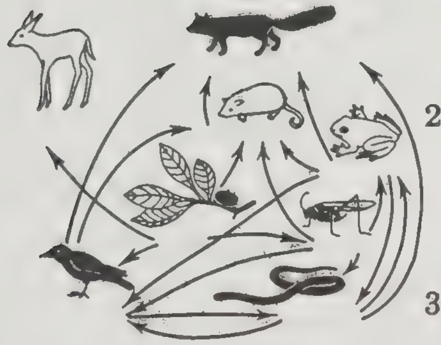


4.A Food Web Story

OBJECTIVE	to understand the relationships within food webs
SKILLS/PROCESSES	analysis, relationships
VOCABULARY	consumer, decomposer, food web, producer
MATERIALS	multiple copies of **The Food Web Story** and **Food Web Starter Sheet** 5 erasable transparencies of the completed food web starter sheet overhead projector (You may use the chalkboard instead of the transparencies and projector.)
COMMENTS	Introduce the concept of a food web before beginning this activity. Be sure students can distinguish between producers, consumers, and decomposers.

PROCEDURE

1. Read **The Food Web Story** aloud or distribute copies for silent reading. Distribute copies of the **Food Web Starter Sheet**. (If you prefer, ask students to construct webs based on the story without the help of the starter sheet. Students rely on clues from the story to construct their webs.)



2. Students draw arrows between organisms that are directly related in the food web. Arrows should always point in the direction of energy flow. If, for example, the flea bites the deer, the flea takes energy from the deer: deer -------> flea.

3. Discuss the completed food webs. As a basis for this discussion, you may wish to reproduce the web on the chalkboard following instructions given by the class.

4. Make five erasable transparencies of the completed food web for use with an overhead projector, or draw the completed web on the chalkboard. Read **Scenario A** below and make the required changes in the web. Begin by erasing the organism(s) directly killed by the disturbance as well as the energy lines flowing to and from the eliminated organism(s). Discuss how each surviving organism is affected by the loss. Repeat for **Scenarios B**, **C**, and **D**; begin each scenario with a complete transparency or with a completed web on the chalkboard.

Scenario A: The hunter removes all the dead, fallen trees for firewood. (Remove the fallen tree from the food web.) Discuss how each surviving organism is affected by the loss.

Scenario B: An insecticide is sprayed to kill gypsy moth caterpillars. It also kills all other insects and arthropods. (Remove the gypsy moth caterpillars, parasitic wasp, fiery caterpillar hunter, spider, flea, aphids, and grubs from the web.) Discuss how each surviving organism is affected by the loss. Why might it be better if scientists discovered an insecticide that killed only gypsy moth caterpillars?

Scenario C: A forest fire rages through the area. (Remove from the web all animals except those that can escape, for example, birds, the hunter, and the deer.) Discuss how each surviving organism is affected.

Scenario D: A logging company clear-cuts the forest. (Clear-cutting is a method of harvesting in which every tree in the area is cut down and hauled away; only a few small plants are left.) Discuss how each organism is affected by the removal of oak trees from the food web.

5. Look at a copy of the complete food web again. Based on the results from the four scenarios, discuss the following questions. Some organisms have only one arrow pointing toward them, for example, the fiery caterpillar hunter and the parasitic wasp. What happens to them when their food source is killed? Some animals in the food web have more than one food source, for example, the owl and the white-footed mouse. Why is it an advantage to have several food sources?

EVALUATION

Ask students to add six new organisms (two producers, two consumers, two decomposers) to the web and to continue the food web story through summer and autumn. Each new organism must have a source of energy. Students may complete this assignment individually or by working in small groups. The end products may be written or given orally to the class using the chalkboard or poster presentations.

Alternately, students may create an entirely new food web story and web that contain at least eight organisms (including insects) found in or around a pond, at least two producers, two consumers, and two decomposers. Each organism, of course, must have a source of energy.

The Food Web Story

Name:

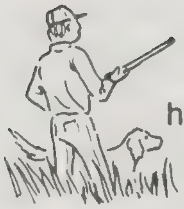
One bright spring day the sun shines onto the forest floor. The warm weather and the moist humus on the forest floor cause the dormant plants to sprout. Up through the dead and decomposing leaves come Jack-in-the-pulpits, spring beauties, and other wildflowers. The old oak trees unfold their new leaves, and within a matter of days the leaves begin to produce food and continue until the fall frosts arrive. Mushrooms pop up around rotting logs, and grubs feast on the fungus and decayed wood. Soon the spring warmth triggers the hatching of gypsy moth eggs, and these young caterpillars crawl from the egg mass onto the tender oak leaves and begin feeding. The abundance of foliage on the oaks and the many wildflowers allow the female deer (doe) to eat well; in turn, she provides food to her fawn in the form of milk. The doe rubs her head against a tree trunk—a flea has just bitten her.

Much spring activity is occurring below the soil surface. Earthworms tunnel through the moist earth, leaving behind little piles of soil in which wildflower seeds will sprout. Above ground, aphids find the young oak leaves juicy and nourishing. The aphids stick their needlelike mouthparts into the oak's stems and suck its nutritious juices. A bright green beetle, the fiery caterpillar hunter, walks up and down the oak trees, searching for its dinner—a gypsy moth caterpillar. Elsewhere on the tree and in the short plants that make up the forest floor, spiders spin webs to catch unsuspecting insects. These tasty items are wrapped in silk and their juices sucked out by the spider.

Another inhabitant of the forest, a white-footed mouse, comes out of its winter home and searches for food—eating wildflower seeds, mushrooms, acorns, and caterpillars it finds along its way. Grackles and robins begin courtship and will soon feed caterpillars and earthworms to their young in nests in the oak trees. Gypsy moth caterpillars not only have enemies like mice and robins, but they also have a tiny wasp as an enemy. This wasp is a parasite of gypsy moth caterpillars. If the female wasp lays her egg under a gypsy moth caterpillar's skin, the young growing wasp will eat the caterpillar from the inside out! Because this kind of wasp kills only gypsy moth caterpillars, it does not emerge from its winter hideaway until gypsy moth caterpillars have hatched. As the season progresses, the young birds and mice must be wary of the owl; the doe and fawn wary of the hunter. . . .

Food Web Starter Sheet Name:

owl


hunter

robin

grackle

white-footed mouse

fiery caterpillar hunter

gypsy moth caterpillars

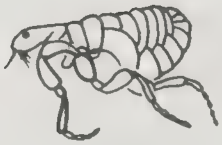
spider

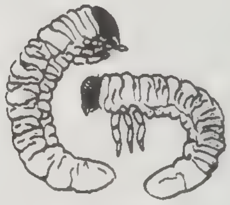
doe

fawn

aphids

oak trees


flea


grubs

wildflowers

fallen tree

dead leaves

fungus

soil

parasitic wasp

earthworms

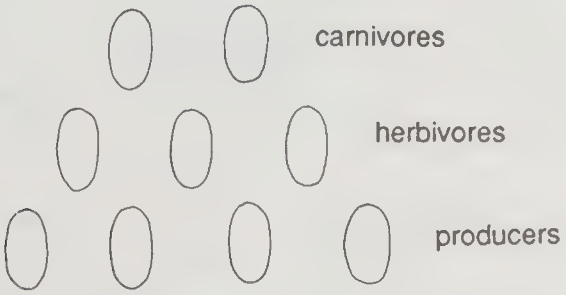
sunlight

4.B Trophic Mobile

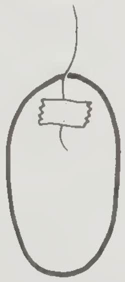
OBJECTIVE	to understand the relationships among levels in the trophic system
SKILLS/PROCESSES	classification, comparison, organization
VOCABULARY	carnivore, consumer, herbivore, photosynthesis, pliable, predator, producer, vegetarian, woody and nonwoody plants
MATERIALS	scissors glue or paste colored pencils transparent tape multiple copies of **Organism Ovals** and **Organism Facts** thread dowels, twigs, straws, or coat hangers cut in 6-inch and 16-inch lengths

PROCEDURE

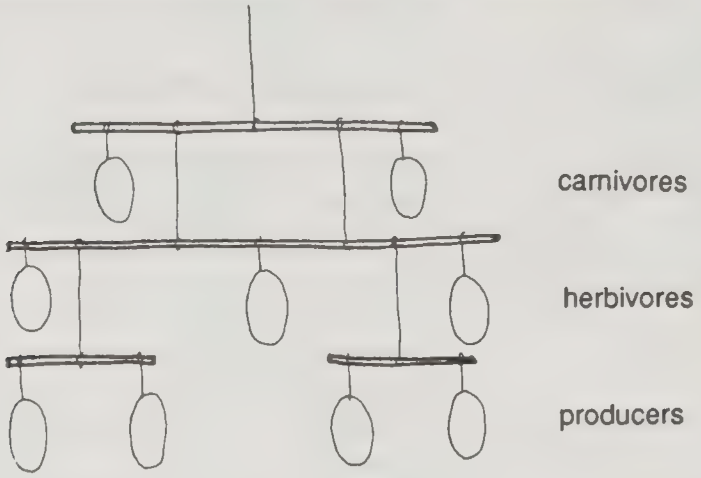
1. Distribute copies of **Organism Ovals** and **Organism Facts**. Students may color the ovals if they wish.
2. Students cut out each organism oval and organism fact, matching each fact to the appropriate organism and gluing the pair together, back to back.
3. Next, students categorize the organisms pictured on the ovals as producers, herbivores, or carnivores, laying them out on their desks like this:



4. Students then attach a 6-inch length of thread to each oval with a small piece of transparent tape.



5. Students complete their mobiles using the materials you have provided. Twelve-inch lengths of thread are used to attach the three levels of the mobile. Balancing is easier if students begin their mobiles from the bottom—with the producers.



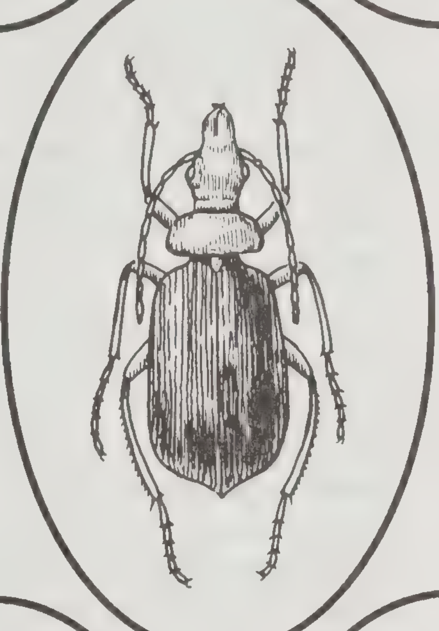
6. As students work, discuss questions like these: What do the producers have in common? At what levels are insects found? How are the red fox and the fiery caterpillar hunter alike? Which animals in the mobile feed on several types of food? Which eats only one food? What happens if that food source disappears?

7. Display the mobiles from light fixtures or by hanging them from a cord strung across the room.

EVALUATION

Working alone or in small groups, students sketch "stay-biles" (similar to the illustration for Step 3) of organisms that live in a given environment—desert, mountain, marsh, or pond. Again, they categorize organisms as producers, herbivores, or carnivores. Alternately, a master "stay-bile" may be executed at the chalkboard with all members of the class contributing.

Organism Ovals



Fiery caterpillar hunters are beautiful blackish-green beetles about one inch in length. They run up and down trees searching for gypsy moth caterpillars, which are their favorite food.

Alfalfa is a relative of clover. Farmers plant fields of alfalfa because it is an excellent food for horses and cattle. Farmers cut alfalfa and allow it to lie in the field until it is dry enough to bale.

Cottontail rabbits eat nonwoody plants and even young trees. Compared to larger mammals, rabbits multiply quickly. Rabbits are important food for such carnivores as coyotes and bobcats.

Red foxes hunt smaller animals and eat them. Red foxes, however, also eat berries and other fruits to balance their diets.

Oak trees begin life as acorns. They grow slowly but can live for hundreds of years. Many old oak trees are a hundred feet tall.

The caterpillars of the gypsy moth are only 1/8 inch long when they hatch. They eat the leaves of trees and grow to be 2-1/2 inches long.

Grasses are nonwoody plants. This means they have soft, pliable stems. Grasses, like all green plants, convert light energy, carbon dioxide, and water into plant growth.

Woodchucks, or groundhogs, live in burrows in grassy areas at the edge of farm fields or woods. Woodchucks are vegetarians and eat a variety of nonwoody plants.

Apple trees are woody green plants that live for many years. The green leaves use light energy, water, and carbon dioxide to produce plant growth. The apples you eat are products of this process, which is called photosynthesis.

4.C

Insects as Decomposers

OBJECTIVE to observe the decomposition process

SKILLS/PROCESSES observation, deduction, record keeping

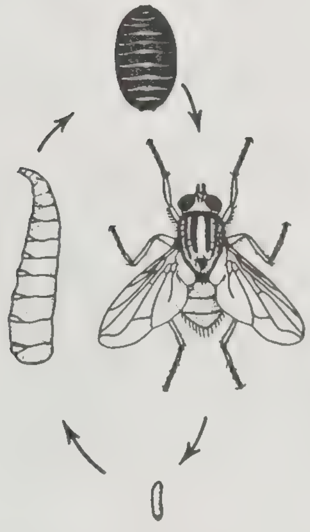
VOCABULARY decomposition, maggot, pupa, pupae, pupate,

MATERIALS

paper cups
sawdust
raw beef liver
granulated sugar
rubber band
colored chalk
glass vials, 1/2-inch diameter
petri dishes, tops or bottoms
dissecting microscope or hand lens
6" × 6" piece of fabric
millimeter ruler

COMMENTS

The majority of insects are herbivores, but whether they are herbivores or carnivores, those that aid in decomposition are called **decomposers.** The blow fly larva (maggot) is a common example. Without decomposers, recycling of nutrients would not be possible, and living organisms would be hard pressed to find suitable nutrients to survive.



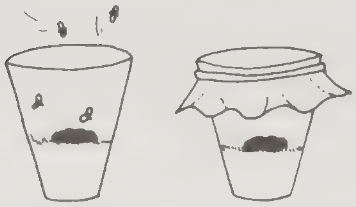
Centuries ago, people believed that maggots spontaneously appeared on rotten meat. We now know that adult female flies deposit their fertilized eggs on meat. The larvae from these eggs feed on the dead flesh and thereby speed up the process of decomposition. They incorporate the energy and nutrients into their own bodies and ultimately into the production of more flies.

Activity 4.C allows students to observe the process of decomposition by flies. Students may complete the activity individually or in small groups. The experiment and its follow-up activities may be written according to a format with which students are familiar or by following this format:

Hypothesis
Materials
Procedure
Observations and Results
Discussion and Conclusion

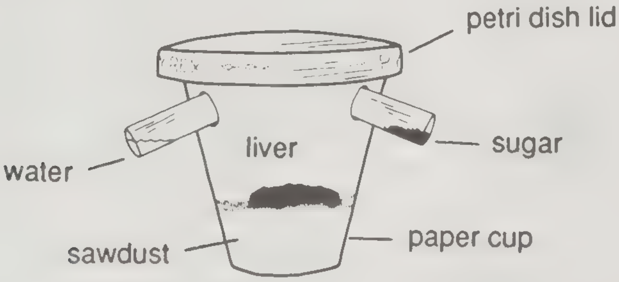
If you schedule this activity during cold weather, you will not be able to collect flies outdoors. Blow fly larvae or pupae can be ordered from biological supply houses and reared to adulthood by following the instructions included with the shipment. If you elect this method, place at least 20 adult flies into an egg-rearing cup with liver in it. Label this cup "adult flies." Add no flies to an egg-rearing cup with liver in it. Label this cup "no flies." See Step 1 below for the details of this procedure. After two days, eggs should have been laid by the adult flies. Place the cup in the refrigerator for 10 minutes. The cool temperature slows the activity of the adult flies and allows you to remove them more easily. Then begin the activity below at Step 3.

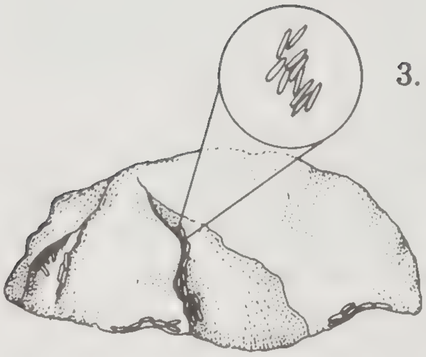
PROCEDURE



1. Prepare two egg-collecting containers by putting sawdust into two paper cups to a depth of 1-1/2 inches. Add a 3" × 3" piece of raw beef liver to each cup. Cover one cup with fabric and secure it with a rubber band. Place both cups outside for two days. Choose a shady location that is safe from neighborhood cats. It may be necessary to keep the liver moist by sprinkling small amounts of water on it. You should notice adult flies buzzing around and landing on the liver in the open cup. After two days, bring the cups into the classroom. By this time, eggs should have been deposited on the liver in the open cup.

2. Use two paper cups to make two fly-rearing containers. Cut two holes in the side of each paper cup 1 inch below the top of the cup. Size these holes so that a glass vial or test tube will fit snugly into each hole. Place 1/8 teaspoon sugar into two vials and a few drops of water into two other vials. Place a vial containing sugar and a vial containing water into the holes in each cup. Put about 1-1/2 inches of sawdust in each cup.



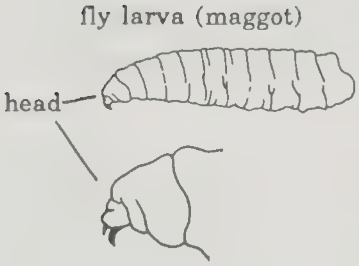


3. Remove the liver from the open egg-collecting container. Using the dissecting microscope or hand lens, students look for white, bean-shaped eggs on the surface and in the cracks of the piece of liver. Each student should sketch an egg and make notes about color and texture and about the number of eggs present. Place the liver that contains eggs into a rearing cup, label the cup, and cover it with the top or bottom of a petri dish.

4. Remove the liver from the fabric-covered cup and look for eggs on it under the dissecting microscope or with a hand lens. Place this piece of liver in the other fly-rearing cup, label the cup, and cover it with the top or bottom of a petri dish.

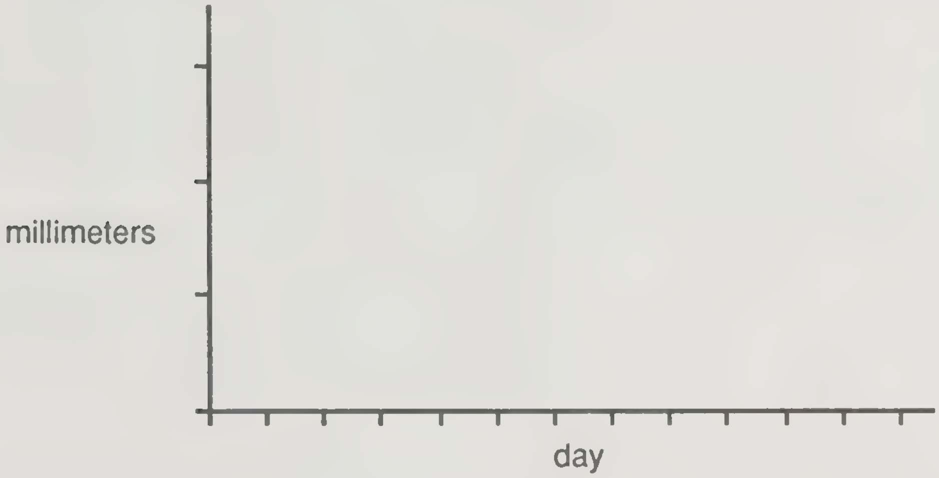
5. Keep the liver moist by adding small amounts of water when it appears dry. Fly larvae should hatch within a few days in the cup containing the liver that had been exposed outdoors. No larvae should be found in the cup containing the liver that had been covered by fabric. As the maggots grow, add more liver if necessary.

6. After two or three days of larval feeding, remove a piece of the decaying liver and ask students to compare its quality to the quality of the liver in the other cup. Students should observe texture, smell, weight, composition, and density.



7. Every two days, remove a few fly larvae for students to observe under a dissecting microscope or hand lens. They should note the shape of the body and mouthparts and sketch a larva on a sheet of paper. Measure the length of about five larvae with a millimeter ruler. Compute the average larval length. Return the larvae to their rearing cup. Record this data every two days. The larval stage lasts five to seven days, but developmental rates vary with temperature and food supply. Students may observe those variations in the follow-up activities described below.

8. At this point, you may choose to begin graphing the growth of the flies on the chalkboard with colored chalk. Use a set of axes as shown below and graph the average length of fly larvae for each measuring day.



9. Students should record when the larvae begin turning into brown, oval pupae. After several flies have pupated, remove a few pupae and observe their shape and texture (they may be buried in the sawdust). Measure them with a millimeter ruler and compute the average pupal length for that day. Return them to the surface of the sawdust in the rearing cup. Repeat every two days throughout the pupal stage, which lasts 7 to 10 days. After all larvae have pupated, remove the liver. Graph the daily average length of a pupa (use a second color on the graph above.)

10. In 7 to 10 days, adults will emerge from the pupal case. When at least four adults have emerged, place the cup in a refrigerator for 10 minutes or in a freezer for 1 minute. The cold temperature will reduce the activity of the flies. Then remove a few adults and quickly measure their length. Return the adults to the cup. Once again, students graph the average length, using a third color on the graph above. Repeat this step for at least five days. The flies will continue to live as long as sufficient sugar and water are supplied.

11. Discuss with the class the following questions. What place do flies occupy in the food web? What happens to dead flesh when flies do not take part in its decomposition? (Refer to the liver that had been covered by fabric initially.) What might happen if there were no flies on earth? In which life stage do flies eat the most food? In which do flies grow? Are the diets of larvae and adults different? How? How is a maggot's body adapted for consuming dead flesh? (The tapered anterior end allows it to tunnel through its food.) How many days does it take for a fly to develop from egg to adult? Why is it advantageous for the life cycle of a fly to be so short? (Flesh may dry out quickly, thereby destroying the food supply. Other flies and such organisms as bacteria, fungi, and mammalian scavengers also complete for the same food resource; therefore, it is beneficial for a fly to consume its food supply and complete its life cycle quickly.)

12. You may conclude the activity at this point or elect to continue it through the next generation in order to give students a sense of the continuity and speed of fly reproduction. If you choose to complete the follow-up activities described below, you will need the eggs from these adult flies.

EVALUATION

Evaluate student understanding of the fly's role in the decomposition process during the discussion generated by Step 11 above. If you prefer, ask students to respond in writing to the final question: Why is it advantageous for the life cycle of a fly to be so short?

FOLLOW-UP ONE

Does temperature affect the development of flies? Use the adult flies that were reared in the above activity to start a second generation. Allow the adults to lay eggs on pieces of liver in three cups. After two days of egg laying, put each cup into the refrigerator for 10 minutes to slow down the activity of the flies and allow you to remove them more easily. Keep one cup of eggs in the refrigerator at temperatures between 40–50°F; keep another at room temperature between 60–75°F; keep the third near a light bulb at temperatures between 85–90°F. Supply plenty of liver to each cup so that the availability of food is not a limiting factor in growth. Keep all liver samples moist. Record temperatures, and measure three or four larvae *from each cup* daily throughout the period of larval development. Graph the average larval length versus time for each of the three treatments. Compare the data from the three treatments and discuss differences found among treatment groups.

FOLLOW-UP TWO

Does the availability of food affect the development of flies? Use the adult flies that were reared in the original activity to begin a new generation. Allow approximately 10 female flies to mate and lay eggs on a 2" × 2" piece of liver. Sexing the flies is unnecessary; if you select at least 20 adults, chances are that half will be female. After two days, remove the adult flies after placing them in the refrigerator for 10 minutes. Use a hand lens or dissecting microscope to look for white, bean-shaped eggs on the liver. Look in cracks in the liver as well as on the surface. Remove the eggs with a small paintbrush, and place approximately 50 onto each of three 1" × 1" pieces of liver. Place each piece of liver in a fly-rearing cup with sawdust in the bottom; cover each cup with the top or bottom of a petri dish.

Do not replenish the liver supply in one cup. Wait until the liver supply becomes low in the second cup; then wait an additional day before adding another 1" × 1" piece of liver. Delay replenishing the liver in this cup throughout the larval stage. Replenish the liver supply in the third cup whenever the supply dwindles, daily if necessary. Label each cup and keep the three cups at the same temperature. Be sure that the liver is kept moist in each cup throughout the experiment.

Measure three or more larvae from each cup daily. Calculate average larval length for each treatment and graph this information versus time. Continue the graph throughout the 10 to 15 days of the larval stage. Compare the results of the three treatments. Discuss the differences among the three treatments if there are any.

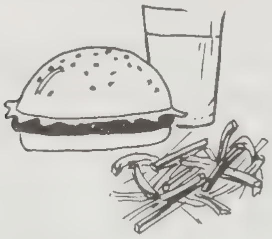
4.D Trophic Levels

OBJECTIVE — to understand our role as consumers in the trophic structure

SKILLS/PROCESSES — observation, analysis, inference, application

VOCABULARY — consumer, food web, producer, top consumer, trophic

PROCEDURE

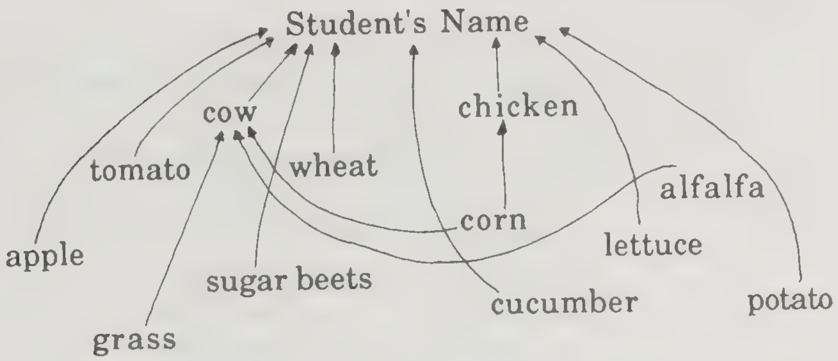


1. The evening before this activity is scheduled, students jot down what they ate for dinner. The following day in class each student divides a sheet of paper into five columns as shown below. In the first column, students record the general name of each food eaten at dinner. In column two, they list the components of each food; in column three, the major ingredients of each component (if an ingredient occurs in more than one food, it is listed only once); in column four, the organisms from which the ingredients were derived. In column five, students record the foods eaten by each consumer organism listed in column four.

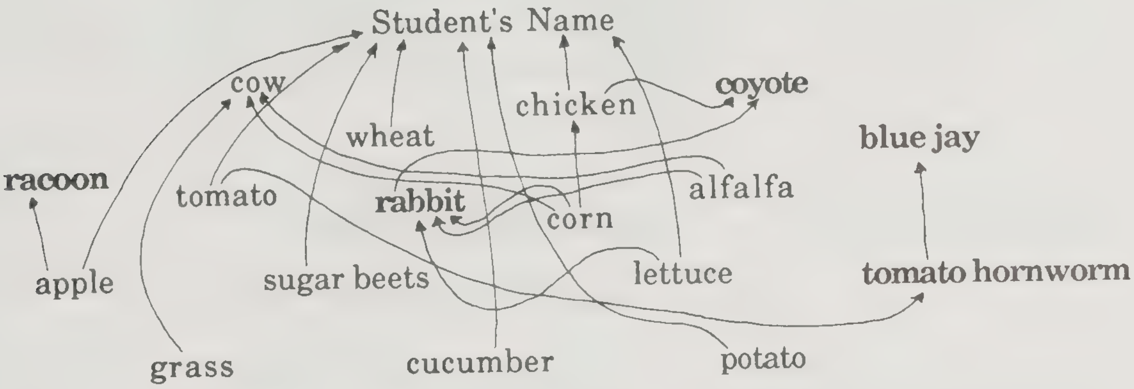
1	2	3	4	5
hamburger	bun	flour	wheat	corn
french fries	hamburger meat	eggs	chicken	alfalfa
apple	pickle	beef	cow	grass
milk	lettuce	cucumber	cucumber	
cookies	ketchup	lettuce	lettuce	
	potato	tomato	tomato	
	apple	potato	potato	
	milk	apple	apple	
	cookies	milk	sugar beets	
		sugar		
		butter		

2. When the five columns are complete, students circle items in columns four and five that are living organisms (plants *and* animals).

3. Next, students draw a food web based on the circled items, putting their own names at the top of the web and drawing arrows from organism to organism in the direction of the flow of energy.



4. Students expand their webs by adding consumers that might share the food resources already in their webs. The appropriate arrows should then be inserted.



5. Discuss the interactions shown on the webs with questions such as these. How many arrows come from our names? How many arrows point toward our names? Why is there this difference? Using the information that students have provided in columns four and five, make a master list at the chalkboard of organisms eaten by the class; list each organism only once. Discuss the number of producers and consumers that students depend on directly and indirectly to provide their daily food. What is the ultimate source of the energy that fuels the food web? [the sun]

EVALUATION

Each student draws a food web based on the following information. A fox catches and eats a rabbit in a field of clover. Birds and grasshoppers are also found in this field. When the webs are finished, each student writes a paragraph below the web comparing the fox in this web to the student in the "dinner-menu" web.

FOLLOW-UP

Organize a debate in which students argue the merits of meat-based versus vegetable-based diets. What are the benefits and risks of one diet over the other? Are moral questions involved in choosing a diet?

Taxonomy: Background Information

Taxonomy is any system by which organisms can be classified into groups based on similarities. Insects, for example, are members of the Phylum Arthropoda. The important features of all arthropods are paired, jointed legs; segmented bodies; and external shells or exoskeletons on the outside of their bodies to which all internal parts are attached. All insects have these characteristics as do all millipedes, crustaceans, and spiders; yet millipedes differ from insects because they have many more body segments and because each of these body segments has two pairs of legs. Millipedes, therefore, are put in a different class—Class Diplopoda (*diplo* = two, *poda* = leg).

Classes are broken down further into orders. The Class Insecta has 27 orders. The insects that make up an order are similar to one another and different from the insects in any other order. A similar process of categorization occurs at the family and genus level. The most basic level of organization is the species. Each species is unique. An example of this taxonomic hierarchy is shown below.

- **KINGDOM** Animalia (animals)
  - **PHYLUM** Arthropoda (arthropods)
    - **CLASS** Insecta (insects)
      - **ORDER** Lepidoptera (moths and butterflies)
        - **FAMILY** Lymantriidae (tussock moths)
          - **GENUS** *Lymantria* (tussock moths)
            - **SPECIES** *dispar* (gypsy moth)

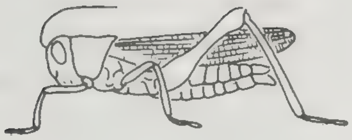
female gypsy moth

5.A Scientific Nomenclature

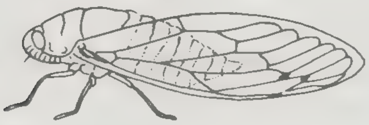
OBJECTIVE	to become familiar with scientific nomenclature, its use and importance
SKILLS/PROCESSES	observing, describing, inferring, classifying
VOCABULARY	genus, scientific nomenclature, species
MATERIALS	multiple copies of **Insect Sheets A–D**

PROCEDURE

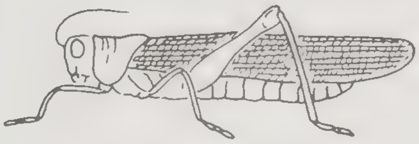
1. Introduce this activity by asking one student to describe a grasshopper, another to describe a locust, and a third to describe a cicada. Controversy will result because these common insect names are used inconsistently. Grasshoppers are sometimes called locusts, cicadas are sometimes called locusts, and locusts are sometimes called grasshoppers. Students will begin to recognize the difficulties in relying on "common" names. The three insects are pictured below with brief descriptions for your reference.



The grasshopper is a member of the Order Orthoptera. Some grasshoppers are pests because they eat crop plants. They are found in treeless, weedy areas.



The cicada is a member of the Order Homoptera. Both adults and nymphs suck juices from trees. Adults are heard during the summer buzzing in trees. They are mistakenly called locusts.



The locust is a member of the Order Orthoptera. It is a type of grasshopper that is large in size and colorful with long wings. Locusts migrate in swarms from one area to another. Locusts are commonly found in Africa.

2. Divide the class into groups and give each group one set of **Insect Sheets A–D**. Each group then determines a common name for each of the four insects, basing their choices on appearance and behavior as described on the handouts.

3. Write the letters **A** through **D** above four columns on the chalkboard. A member of each group writes down the insect names they have chosen in the appropriate columns. Discuss these names. What factors of appearance or behavior were most often used to create names? Are the names unique to a given illustration or could they be used with the other illustrations? Can students think of other insects to which these names might apply? Vote to determine the best name for the insects pictured on the four sheets.

4. At this point, ask students to consider how they would go about requesting information from a person in Yugoslavia about the insect represented in one of the illustrations. What problems might there be?

5. Ask the groups to reexamine the four illustrations with this added piece of information: the four illustrations picture the *same insect* in a different life stage or as male or female. Each group then decides upon a single name for the insect shown in the four illustrations. Compare the names chosen, discuss the reasons for the choices, and vote to select the best name. The class will by now more fully recognize the problems in assigning a "common" name to a particular species.

6. Share the common name of the insect pictured in the four illustrations. It is the **gypsy moth**. Its scientific name is *Lymantria dispar* (*lymantria* = destroyer, *dispar* = different and refers to the difference between the male and female).

7. Discuss the usefulness of **scientific nomenclature**. Incorporate the following information into this discussion.

   The classification system was developed by Swedish naturalist Carolus Linneaus over 200 years ago. All names are in Latin and each animal or plant is given a two-part name—a genus name and a species name. You might compare this system to our use of a family name such as Smith and an individual name such as Sarah. Latin was chosen because it was traditionally the "language of scholarship." Scientists, clergymen, historians, and other learned people regularly used Latin in books and articles and in teaching.

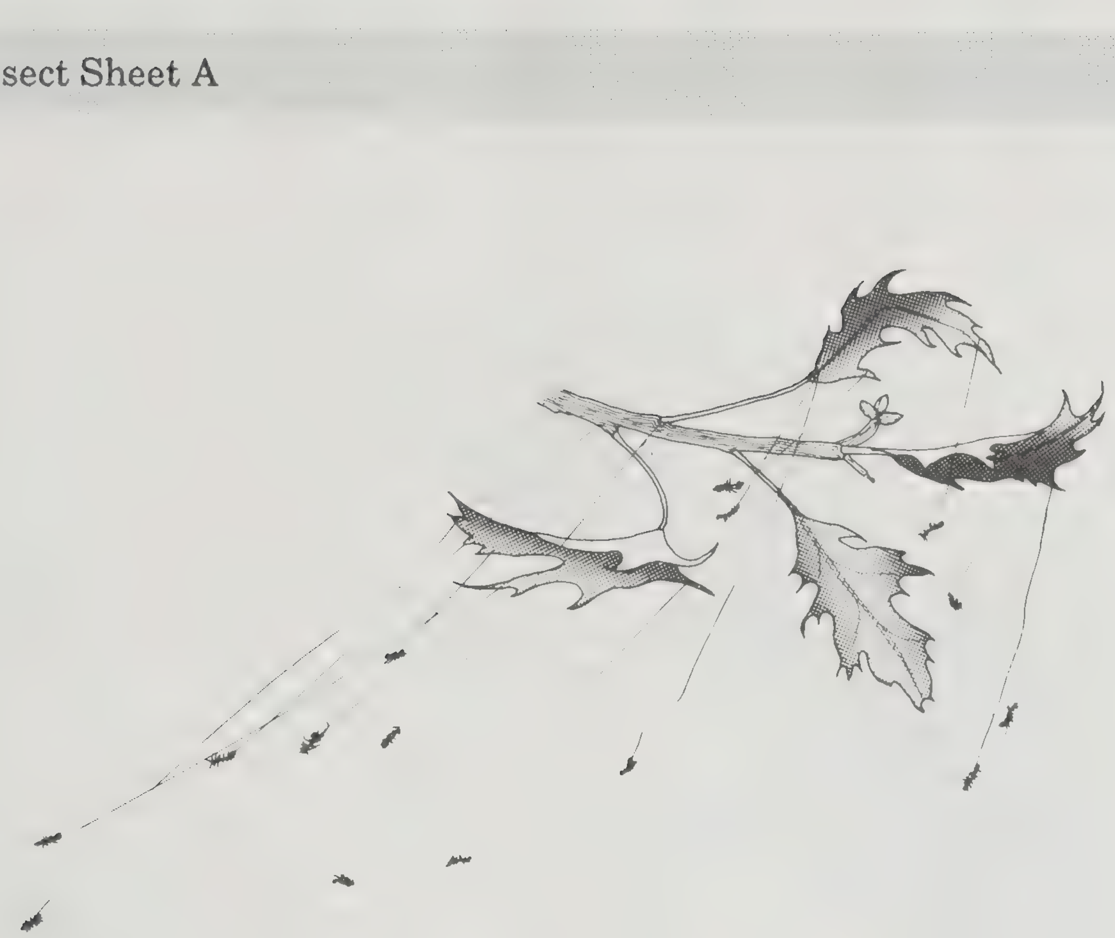
   Individuals within a genus share general characteristics, but one or more unique features allow each individual to be assigned a species name. The genus name is always capitalized and the species name always begins with a lowercase letter. The two names always appear in italics or are underlined when italics are not available.

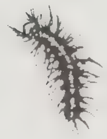
8. Conclude the activity by introducing the taxonomic hierarchy given earlier in Section 5: Background Information. By putting the hierarchy on the chalkboard, you can place the gypsy moth more completely within the total classification system—from kingdom to species.

EVALUATION

Each student jots down on a slip of paper two advantages in using scientific nomenclature. Collect these slips and ask a "jury" to read them aloud, putting duplicates aside and listing the others on the chalkboard. If the class comes up with new advantages at this time, add them to the list.

Insect Sheet A

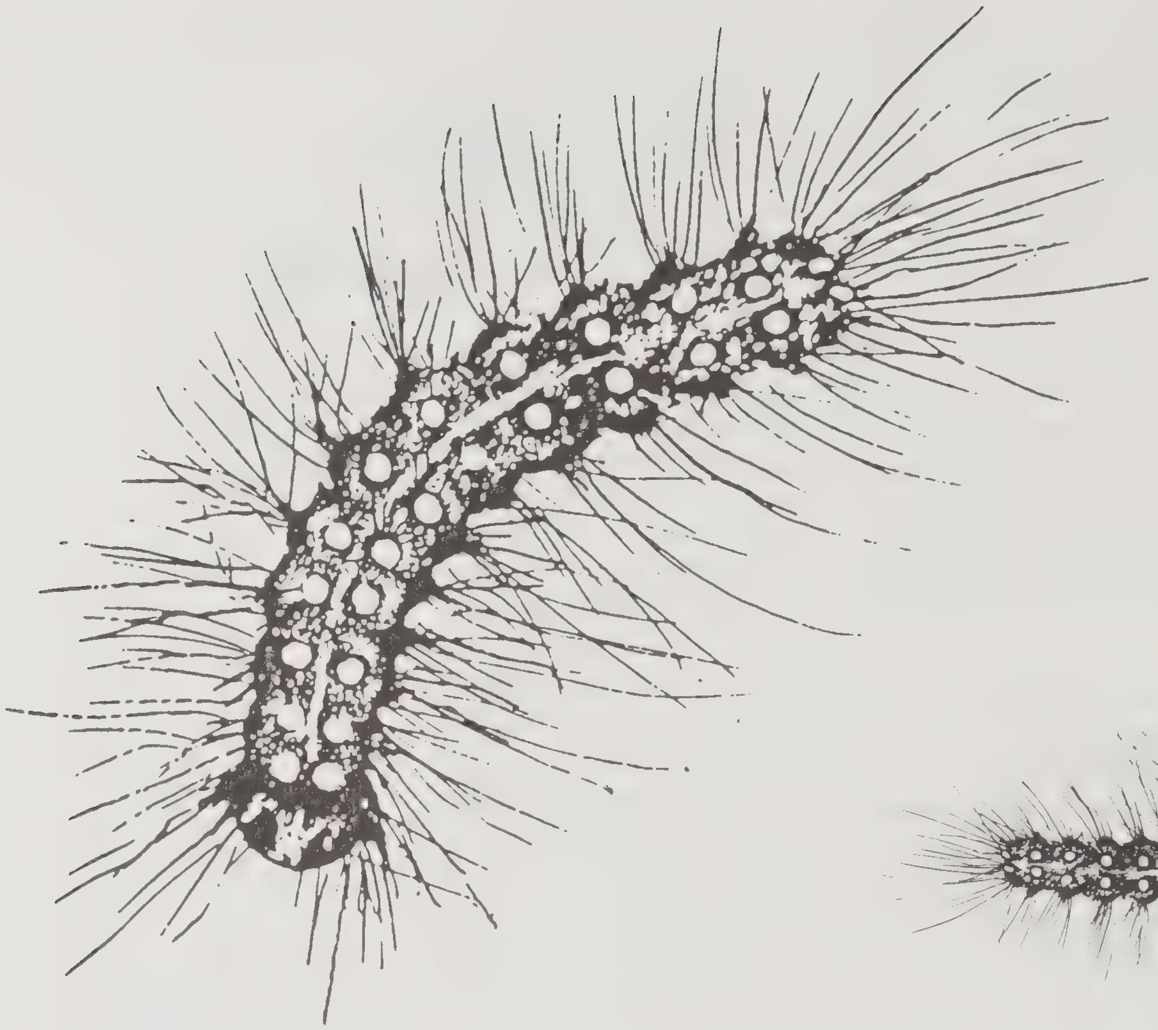


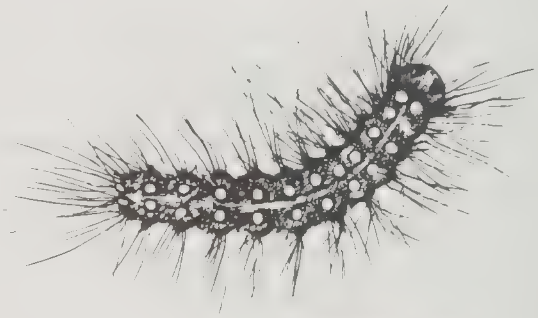


(actual size)

This larva has long black hairs on its body. The back is dark with some lighter yellowish-orange spots. This tiny caterpillar will feed on oaks and birches. It has the ability to travel from one place to another by dangling itself on the end of a silken thread. The wind catches the thread and the buoyant larva is transported to a new home.

Insect Sheet B

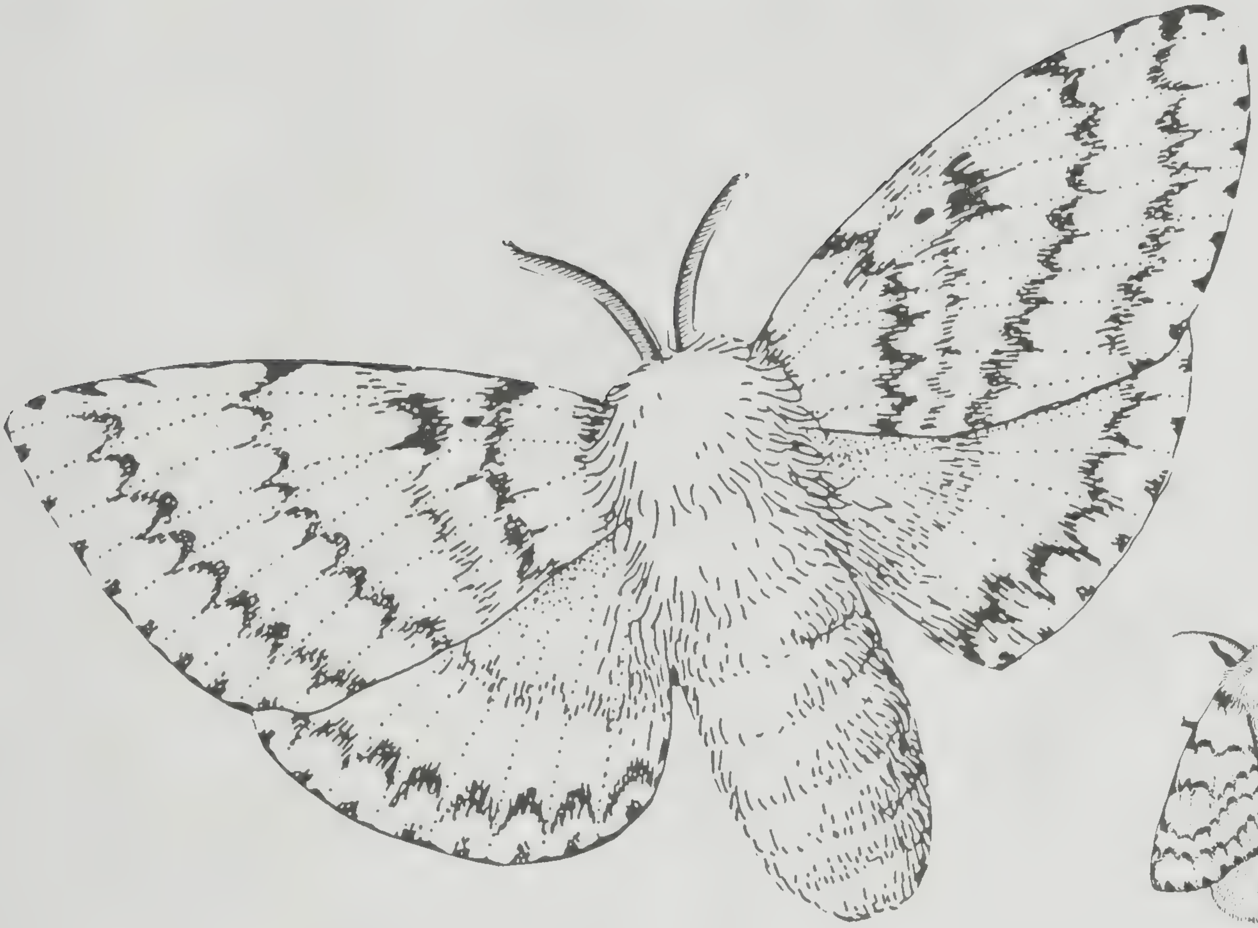




(actual size)

This large hairy caterpillar is 1-1/2 to 2-1/2 inches long and has five pairs of blue and six pairs of rust-colored spots along its back. It will feed on over 500 species of trees and shrubs but prefers the leaves of oaks.

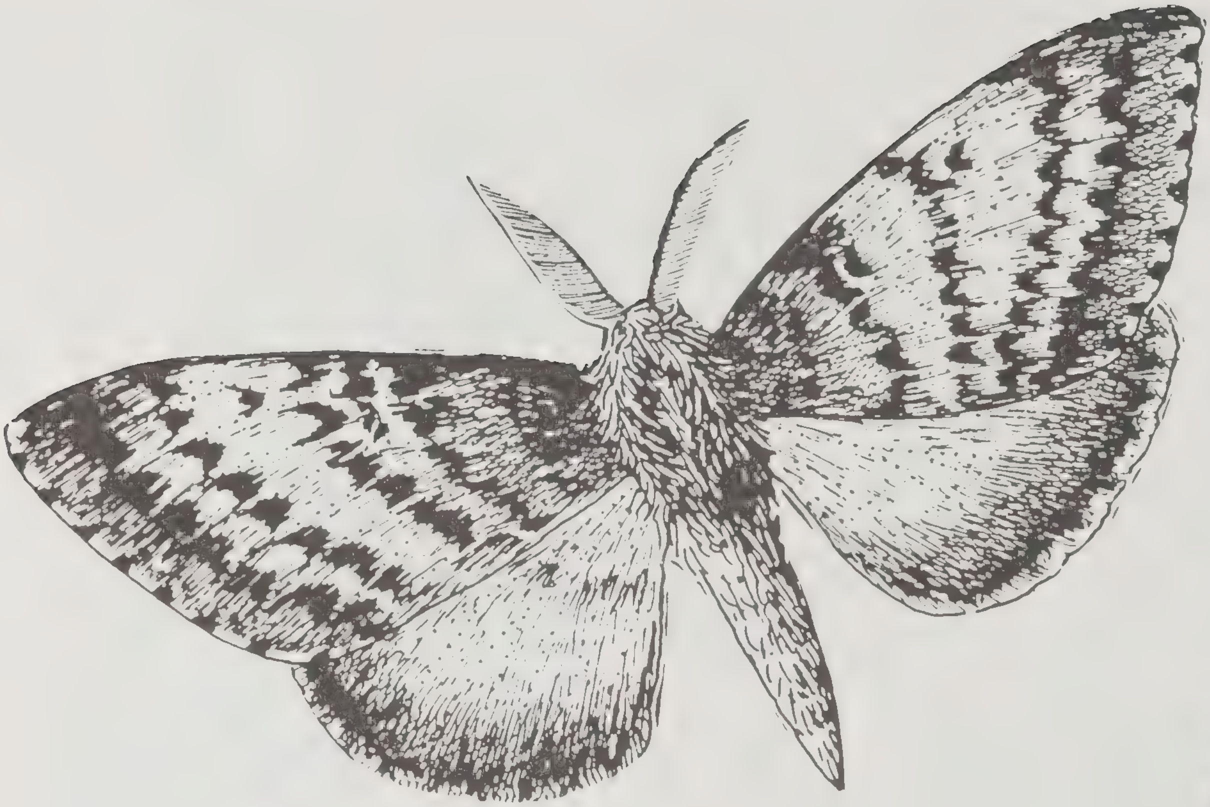
Insect Sheet C



(actual size)

This insect has a hairy, cream-colored body and wings with black markings. It cannot eat and is unable to fly. This insect is usually found in forests.

Insect Sheet D



(actual size)

This insect is brown with dark brown markings on its wings. The antennae are long and feathery. This flying insect is unable to eat.

5.B

Six Major Taxonomic Orders of Insects

OBJECTIVE

to identify characteristics that place insects into six major taxonomic orders

SKILLS/PROCESSES

observing, comparing, classifying, synthesizing

VOCABULARY

Diptera (DIP-ter-ruh)
Siphonaptera (sy-fun-AP-ter-ruh)
Isoptera (eye-SOP-ter-ruh)
Odonata (oh-dun-ATE-uh)
Lepidoptera (lep-i-DOP-ter-ruh)
Hymenoptera (hi-men-OP-ter-ruh)

MATERIALS

scissors
colored pencils
glue or cellophane tape
multiple copies of **Insect Parts** and **Paste-up Boxes 1** and **2**
optional: multiple copies of **Answer Sheet**

COMMENTS

Younger students will need opportunities to pronounce these words often enough to become familiar with them; perhaps a spelling quiz would be useful.

PROCEDURE

1. Distribute copies of **Insect Parts** and **Paste-up Boxes** and direct students to construct six insects by arranging combinations of head, thorax, and abdomen. They should refer to the text on the paste-up sheets for hints on how to make these insects so that each of the six orders will be represented by one insect. Students may color these insects if they wish.

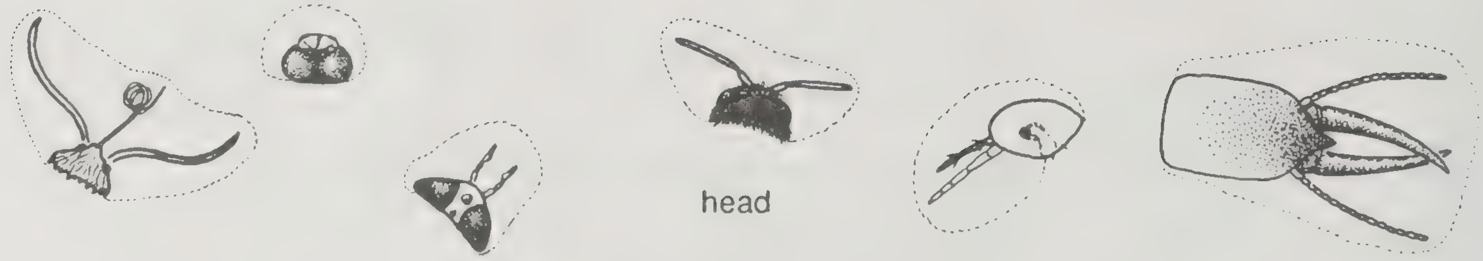
2. Ask students to check with you before pasting their insects into the order boxes. If you prefer, you may give the **Answer Sheet** to a jury of several students who can do this verification for you.

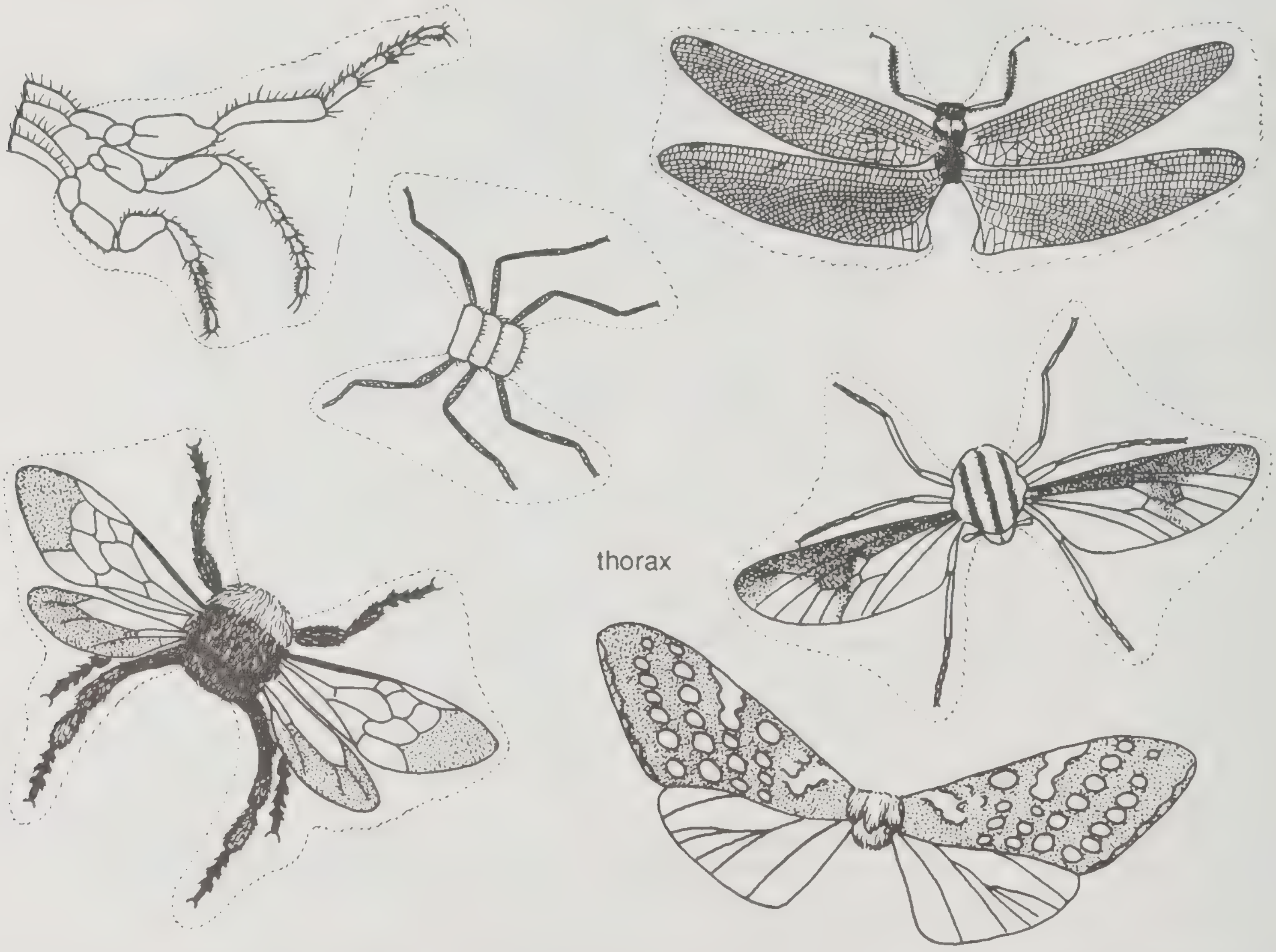
3. After the insects have been pasted in the correct boxes, review the characteristics of the six orders and identify each insect by its common name: dragonfly, moth, flea, bee, fly, and termite.

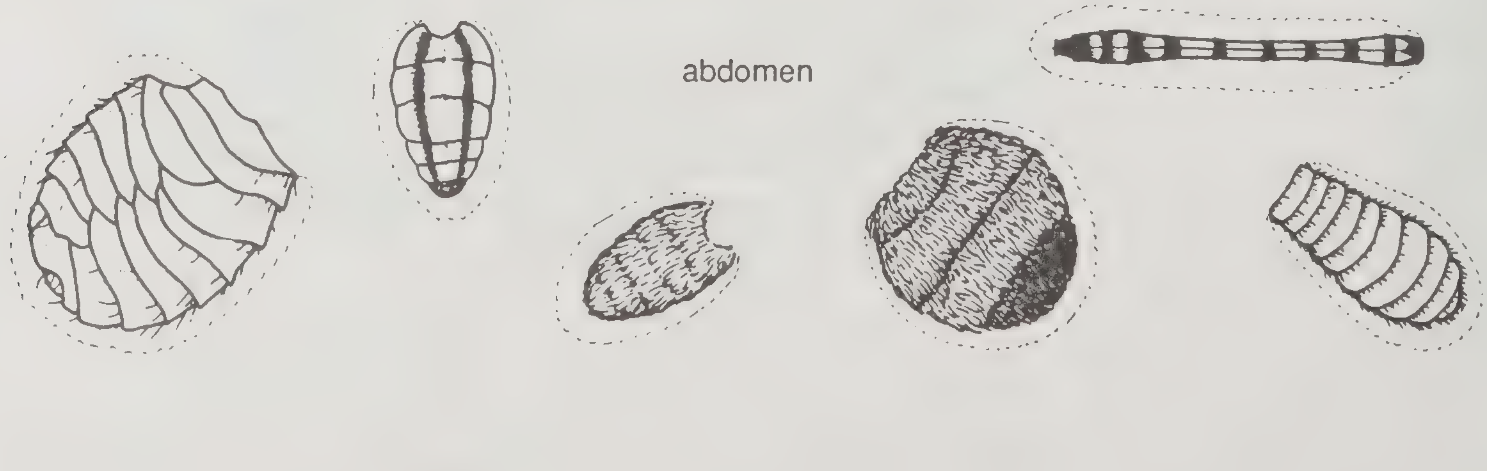
EVALUATION

List the orders used in this activity on the chalkboard, numbering them from one through six. Ask students to count off in sixes. Each student then draws an imaginary insect that fits the definition of the order that matches his or her number. The description in the box may be used, but the insect in the box should not be copied. Collect the drawings and redistribute them at random. Each student then identifies the order to which the insect he or she received belongs. The illustrator of each insect should confirm or dispute this label.

Insect Parts







Paste-up Boxes 1

Name:

Order Diptera

front pair of wings membranous; rear wings reduced to small knobbed structures called halteres; head wedge-shaped with large eyes; antennae short and straight

Order Siphonaptera

no wings present; legs long and wide and used for jumping; body flattened sideways; mouthparts form a short, straight sucking tube

Order Isoptera

no wings present; legs simple and used for walking; head squarish and very large, long pinching mouthparts

Paste-up Boxes 2 Name:

Order Odonata

large insects with two pairs of nearly alike membranous wings; very long, thin abdomen; eyes very large and round

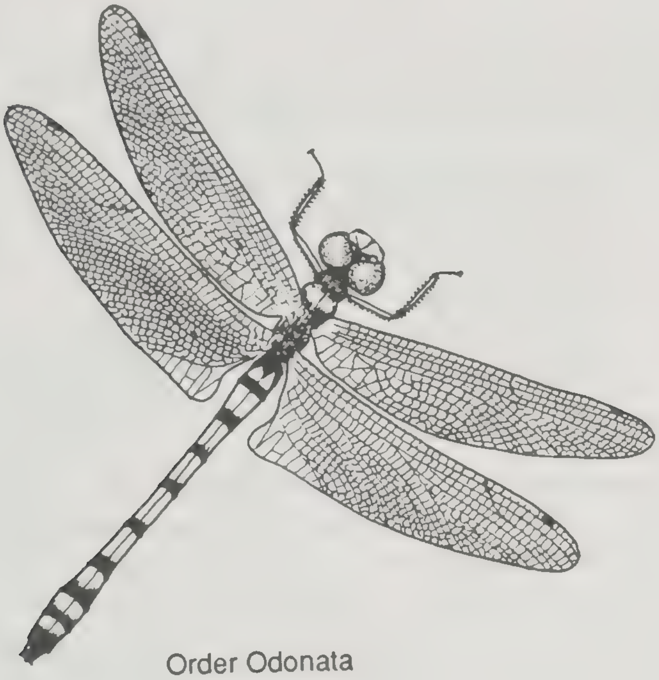
Order Hymenoptera

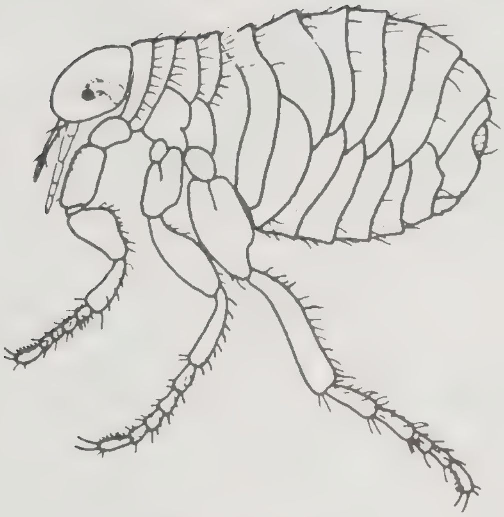
hairy body; two pairs of membranous wings, hind pair smaller and narrower; round, hairy abdomen; legs hairy and wide to carry pollen

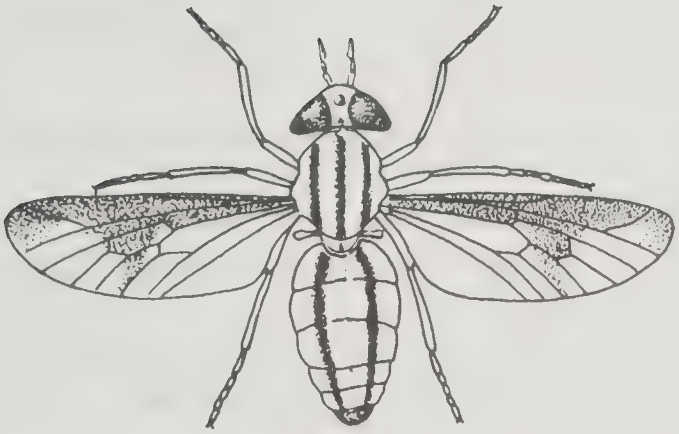
Order Lepidoptera

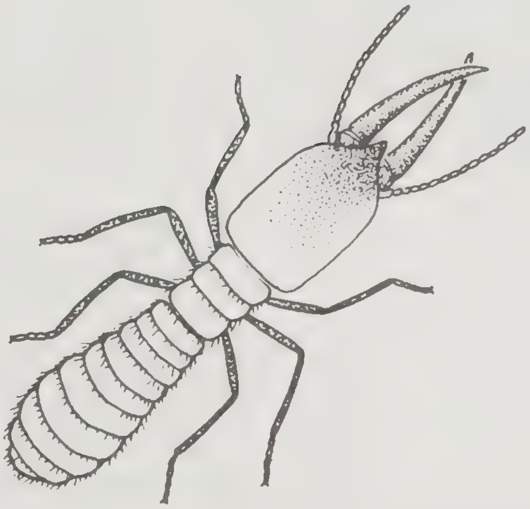
two pairs of wings covered with scales that can be brightly colored; head and body covered with hair; mouthpart a long coiled tube used for sucking nectar from flowers

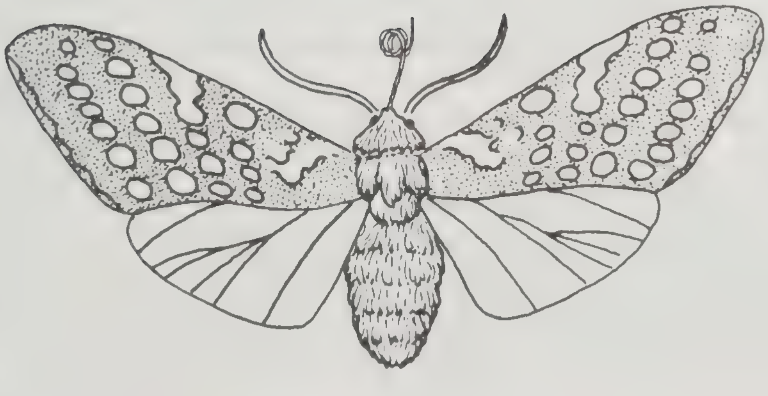
Answer Sheet

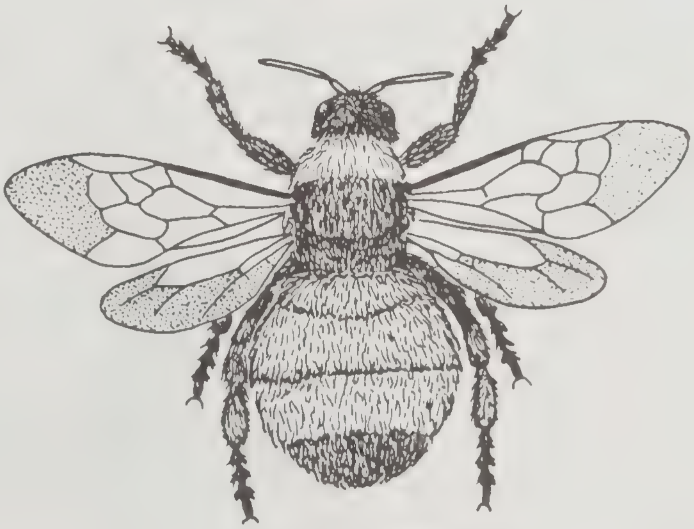

Order Odonata


Order Siphonaptera


Order Diptera


Order Isoptera


Order Lepidoptera


Order Hymenoptera

5.C Observing and Collecting Insects

OBJECTIVE

to become familiar with the major taxonomic orders of insects through direct observation or through an insect collection

SKILLS/PROCESSES

observing, collecting, comparing, classifying, identifying

MATERIALS

field guides
insect sweep nets
killing jar
vials, bottles
envelopes
insect pins or straight pins
spreading board (optional)
sheets of styrofoam or corrugated cardboard
multiple copies of **Characteristics of Eleven Common Insect Orders 1** and **2**

COMMENTS

Collection is an ongoing project over several weeks or even throughout the semester or year. It can be carried out at varying levels of intensity depending upon the overall science curriculum and the age and interests of students. A collection may be made by the teacher or by the entire class working as a unit or in small groups. Collections may also be created by individual students with special interests. The procedure for preparing an insect collection is not given here but can be found in the references listed below. The terms **simple** and **complete metamorphosis** used in the handout are defined in Section 6: Background Information. Instructions for constructing sweep nets, killing jars, and spreading boards are given in the Appendix.

Borror, D.J., and R.E. White. 1970. A Field Guide to the Insects of America North of Mexico. Peterson Field Guide Series 19. Houghton Mifflin Co., Boston, Mass.

Jaques, H.E. 1947. How to Know the Insects. Pictured Key Nature Series. W.C. Brown Co., Dubuque, Iowa.

Zim, H.S., and C. Kottam. 1956. A Guide to Familiar American Insects. Western Publishing Co., Golden Press, New York.

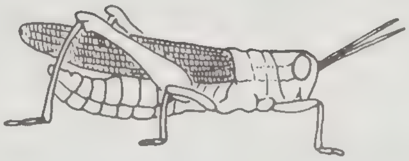
PROCEDURE

1. If your decision is to introduce common insect orders through observation rather than collection, arrange opportunities for students to catch, identify, and release insects in a variety of habitats and at a variety of times of day. A light trap on the school grounds will attract insects at night and increase opportunities for observation. Copies of **Characteristics of Eleven Common Insect Orders** are useful, as are the references listed above.

2. If your decision is to begin an insect collection, decide how important your role will be, whether the project will be a class undertaking, or whether it will belong to one or more students with special interest in the collection of insects. However the collection is assembled, the class should have opportunities to make comparisons, classifications, and identifications. Your observations over time serve to evaluate the success of this activity.

Characteristics of Eleven Common Insect Orders 1

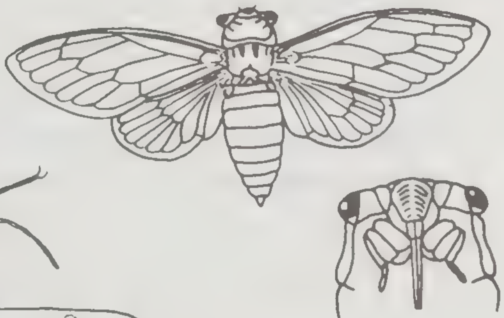
Order Odonata
large insects with unfolded, nearly alike membranous wings; eyes big; chewing mouthparts; simple metamorphosis



Order Orthoptera
hind legs large and strong for jumping; front wings tough, long, and narrow; hind wings membranous; chewing mouthparts; simple metamorphosis

Order Dictyoptera
legs adapted for running and walking; front wings tough; hind wings membranous; chewing mouthparts; simple metamorphosis

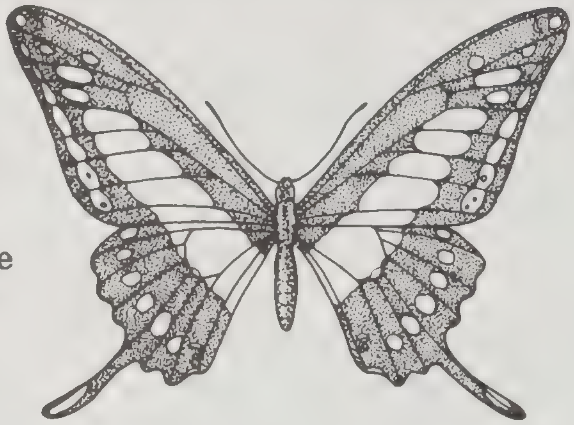
Order Hemiptera
top half of front wing thick and leathery, bottom half membranous; hind wing membranous; piercing-sucking mouthparts that form a beak coming from the front of the head; simple metamorphosis



Order Homoptera
two pairs of membranous wings or no wings at all; piercing-sucking mouthparts that form a beak coming from the back of the head; simple metamorphosis

Order Coleoptera
front wings thick and leathery or brittle and hard; hind wings membranous and folded under front wings at rest; chewing mouthparts; complete metamorphosis

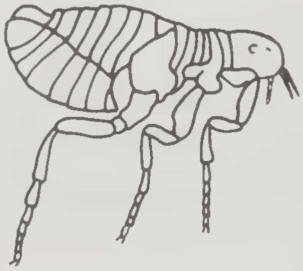
Order Lepidoptera
two pairs of wings covered with scales, often colorful; adult mouthparts a long, sucking tube; complete metamorphosis; larvae have chewing mouthparts and are called caterpillars



Order Hymenoptera
two pairs of membranous wings or no wings at all; base of abdomen usually constricted; chewing or chewing-sucking mouthparts; complete metamorphosis

Order Diptera
front pair of wings membranous; hind wings reduced to small knobbed structures called halteres; piercing-sucking or sponging mouthparts; complete metamorphosis

Order Siphonaptera
no wings; jumping insects with long legs; small body flattened sideways; mouthparts a sucking tube; complete metamorphosis



Order Isoptera
wings present only in those adults that reproduce; workers and soldiers are wingless; social insects that live in colonies; chewing mouthparts; simple metamorphosis

5.D Library Research: Eleven Insect Orders

OBJECTIVE

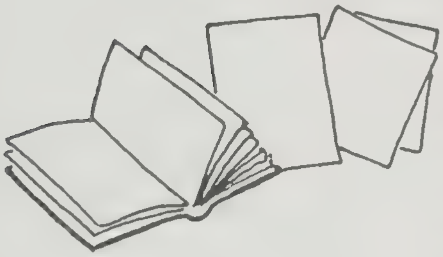
to use library research skills to learn more about insect orders

SKILLS /PROCESSES

locating references on a specific topic, reading for specific information (skimming), note taking, organizing, writing

VOCABULARY

Hymenoptera (hi-men-OP-ter-ruh) wasps, bees
Isoptera (eye-SOP-ter-ruh) termites
Orthoptera (or-THOP-ter-ruh) crickets, grasshoppers
Dictyoptera (dik-tee-OP-ter-ruh) cockroaches, preying mantises
Diptera (DIP-ter-ruh) flies, mosquitoes
Coleoptera (coal-ee-OP-ter-ruh) beetles
Lepidoptera (lep-i-DOP-ter-ruh) butterflies, moths
Siphonaptera (sy-fun-AP-ter-ruh) fleas
Odonata (oh-dun-ATE-uh) dragonflies, damselflies
Homoptera (home-OP-ter-ruh) aphids, scales, leafhoppers
Hemiptera (hem-IP-ter-ruh) true bugs



MATERIALS

access to a library or other collection of references on insects
copies of **Characteristics of Eleven Common Insect Orders 1** and **2**; see Activity 5.C

COMMENTS

The twenty-seven insect orders are not equally well represented in the literature, especially in materials for young students. Eleven relatively common orders are introduced in this activity.

Depending upon the age of your students, you may wish the librarian to bring together useful materials in a specified area of the library or in your classroom. The librarian may also need time to send for materials from other libraries.

PROCEDURE

1. Divide the class into groups and assign one of the eleven insect orders to each group. Working together, each group produces a report that includes information on the identifying characteristics of its assigned order and examples of insects in that order. Drawings, tables, and other graphic material may be included. Students will probably need models for the correct citation of their sources.

2. The format for these reports may vary: written reports with illustrations and covers, oral reports with topics divided among the members of the group, poster presentations, bulletin board displays.

3. If students completed Activity 1.B, they may now be able to identify the insect pictures by order.

EVALUATION

Write a note to each group in which you evaluate its report. The criteria you use will depend upon the requirements you established for this assignment.

6. Insect Development: Background Information

Insects have one basic anatomic pattern (see Section 2, Definition of Insects). The three body regions—head, thorax, and abdomen—and all appendages of an insect are enclosed inside an exterior skeleton. This exoskeleton is made of chitin (KITE-n), a very hard substance. Because the exoskeleton is rigid and strong, it protects the insect against the elements and against its enemies. The exoskeleton is also the main support for the insect's body and the base for muscle attachment and movement. Insect body structure is obviously successful because insect fossils have been found in rocks 400 million years old.

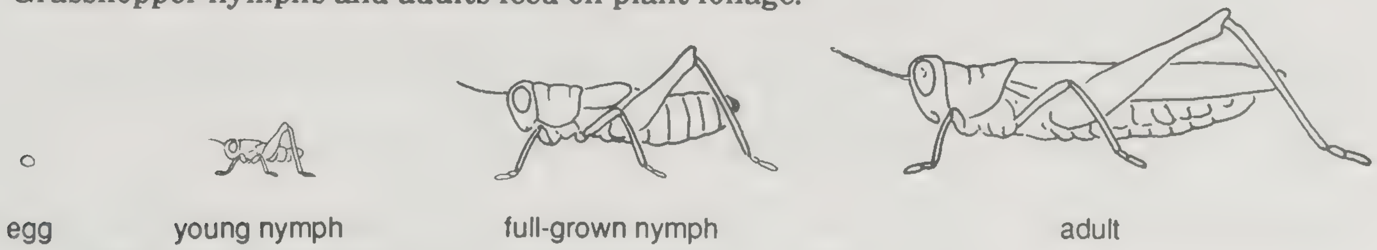
Although the rigidity of the exoskeleton is beneficial to the insect, it also forms an unexpandable prison. If the insect is to grow, it must cast off its old exoskeleton. Before the old exoskeleton is shed, a newer and softer one forms just underneath the old one. When the old exoskeleton splits, the insect climbs out and expands to its new size while the new exoskeleton is still soft and flexible. The new exoskelton soon hardens and is again effective protection. This process is called molting.

Each time an insect molts, visible changes occur. This growth process is called metamorphosis. The changes in the insect's body may be slight, and the feeding habits of the young insect and of the adult may be similar. When that is the case, the insect is said to undergo simple (incomplete) metamorphosis. The development of a grasshopper, an insect that undergoes simple metamorphosis, is shown on the following page.

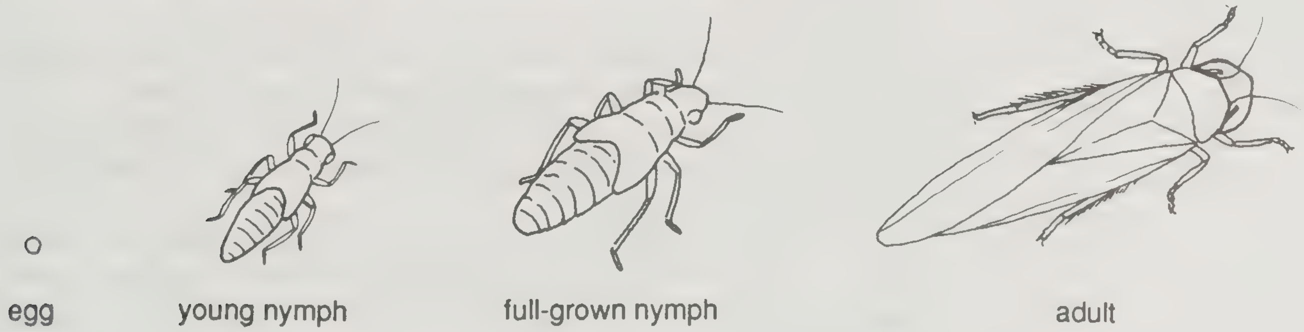
As some insects develop, they undergo great changes both externally and internally. Major changes can also occur in feeding habits. These insects, like the June beetle shown on the following page, are said to undergo complete metamorphosis. The life cycle of the gypsy moth also illustrates complete metamorphosis. During the larval stage, the gypsy moth eats almost continuously and molts several times. *All* gypsy moth growth occurs during this stage. Then the larva molts to the pupal stage, during which time great cellular changes occur. The adult moth does not eat; its only purpose is to reproduce. The energy obtained during larval feeding provides the raw materials for egg and sperm production when the larva becomes an adult.

Simple Metamorphosis

Grasshopper nymphs and adults feed on plant foliage.

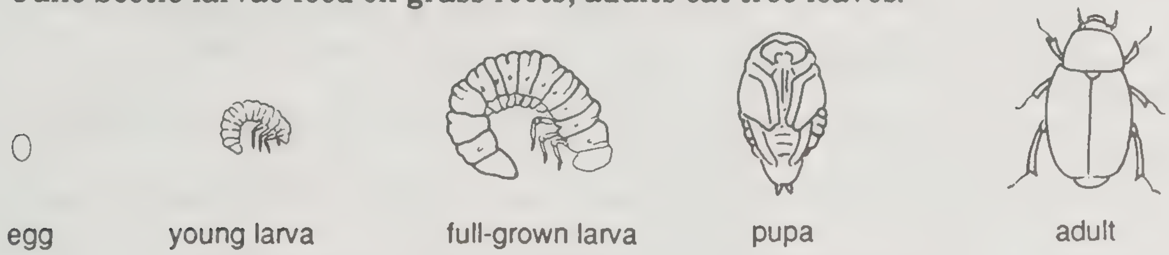


Leafhopper nymphs and adults suck plant juices.

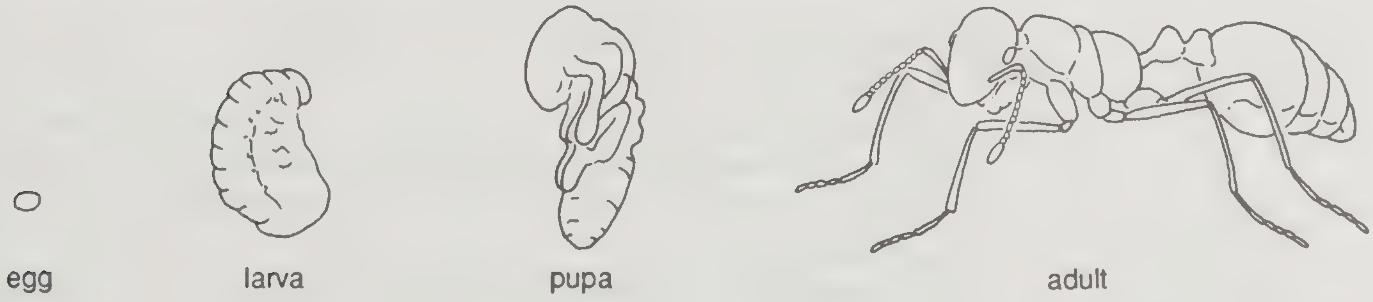


Complete Metamorphosis

June beetle larvae feed on grass roots; adults eat tree leaves.



Ant larvae are fed a predigested mixture by the adults; adult ants eat almost anything.



6.A Insect Shape and Purpose

OBJECTIVE to understand the relationship between insect shape and purpose

SKILLS/PROCESSES observation, analysis, comparison, application

VOCABULARY chitin, complete metamorphosis, cross section, exoskeleton, molt, nymph, ovipositor, simple metamorphosis, vertebrates

MATERIALS multiple copies of **Worksheets A–F**

COMMENTS

This activity is important because it encourages students to look at nature in a more enlightened way and to discover how organisms are adapted to their environment. If you hesitate to use the amount of paper that these worksheets require, try one of the following modifications:

1. A bulletin board display on insect shape and purpose, with one copy of each worksheet included as part of the display. Each student then answers the questions on a separate sheet of paper.
2. Copy each worksheet onto a transparency and present the material via an overhead projector. Students write the answers or share them in discussion.

PROCEDURE

1. Students complete each worksheet as directed.

Worksheet A:	The exoskeleton of an insect can provide camouflage as well as physical protection.
Worksheet B:	The exoskeleton is the base for muscle attachment.
Worksheet C:	The mouthparts of an insect reflect its eating habits.
Worksheet D:	The legs of an insect can be specialized for various functions.
Worksheet E:	Many insects have specialized structures for mating and egg-laying.
Worksheet F:	Molting takes place as insects grow larger.

2. The answers to the worksheets are given below.

Worksheet A
The correct coloring for the five insects on this sheet is evident from their descriptions. A written or oral justification of the reasoning behind the colors chosen may be requested.

Worksheet B
The cross section on the left is that of a moth; the cross section on the right is that of a bird.

Worksheet C
1C, 2G, 3B, 4D, 5F, 6A, 7E

Worksheet D
1B, 2G, 3A, 4C, 5E, 6J, 7D, 8H, 9F, 10I

Worksheet E
1B, 2C, 3D, 4A, 5E

Worksheet F
Gypsy moths go through six molts. They undergo complete metamorphosis. Because the exoskeleton is the base for muscle attachment, it must be rigid and able to hold its shape when the insect's muscles contract and expand.

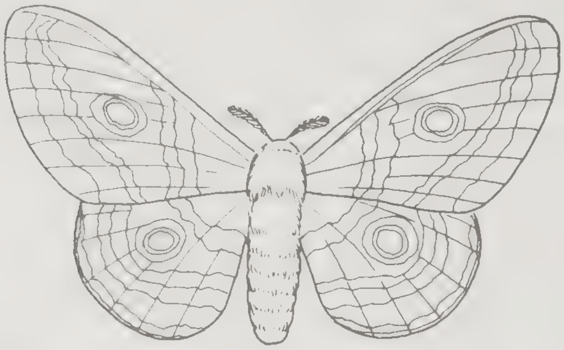
EVALUATION

The completed worksheets provide the evaluation for this activity.

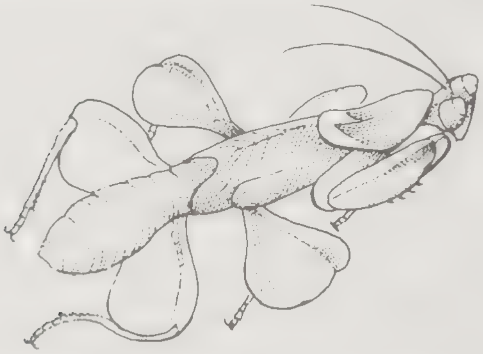
Worksheet A: Exoskeletons for Protection Name:

The exoskeletons of insects come in a variety of shapes, textures, and colors. Some insects are brightly colored to attract a mate or to warn an enemy. Others may be drab or strangely shaped to hide from predators or to ambush prey.

Under the picture of each insect is a description of some of its living habits. Read each description; then color the insect appropriately.



When this light brown moth is threatened, it quickly flashes its wings. The black and yellow "eyespots" are only patterns on the wings, but they frighten away predators.



This colorful mantis is a predator that spends much of its time on bright pink flowers. Its color blends in so that it can ambush prey.

This planthopper makes its home on thorny bushes. There it blends in with the thorns on the plant's stems.

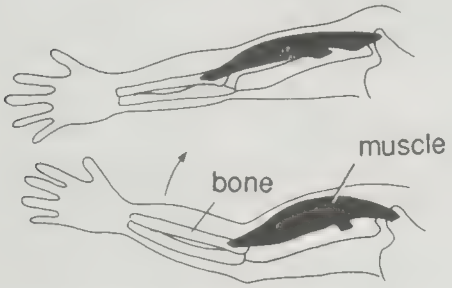
The katydid is colored like the leaves on which it feeds. Its wings have veins that make them look even more like leaves.

The walking stick has a fitting name. Its legs and antennae are long and delicate like small twigs. It walks very slowly so that predators do not notice its movement. The walking stick is a vegetarian.

Worksheet B: Exoskeleton and Muscle Attachment   Name:

In humans and other vertebrates, the support for the body and muscle movement is an interior bony skeleton. Insects do not have interior skeletons. Instead, their muscles are attached to the hard exterior exoskeleton.

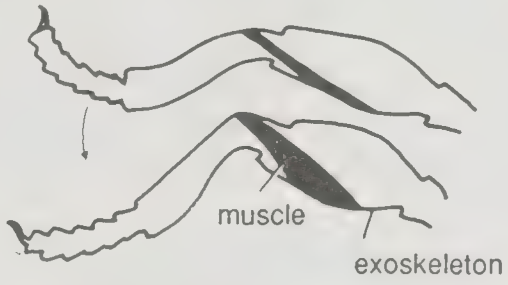
Vertebrates



muscle relaxes, limb extends

muscle contracts, limb bends

Insects



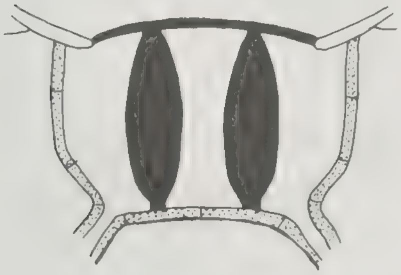
internal skeleton: bone
An internal skeleton supports the human body. Muscle is attached to bone.

external skeleton: chitin
An exoskeleton supports the insect body. Muscle is attached to the exoskeleton of chitin.

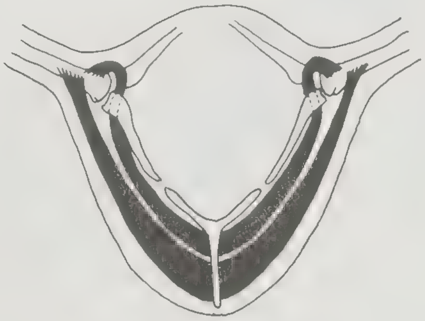
When a muscle contracts, it pulls on the parts of the skeleton to which it is attached. In each of the four pictures above, draw arrows that indicate where each muscle is attached. When the muscle contracts, it pulls at the points of attachment and those parts of the skeleton move.

A cross section is a view of an object's interior. A slice of bread is a cross section of the loaf. One of the cross sections below is through the breast of a bird. The other is through the thorax of a moth. Provide labels that identify which is which.
Give a reason for your answer: ____

____



Cross section of _______________



Cross section of _______________

What type of skeleton does a moth have? _______________

What type of skeleton does a bird have? _______________

Worksheet C: Mouthparts of Insects Name:

The mouthparts of an insect usually reflect its feeding habits. Match each of these insects with one of the mouthparts below based on the description of its food and feeding habits.

---

1 ___

The leafhopper uses its hard, needlelike mouthparts to pierce plant stems. Then it sucks the plant's juices through the hollow, strawlike part of its mouth.

2 ___

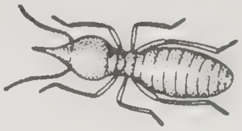
Immature dragonflies live underwater. They have mouthparts that quickly swing out to catch such prey as small fish, aquatic insects, and tiny tadpoles.

3 ___

Grasshoppers eat plants. Their jaws work like small, blunt scissors that clip out little pieces of the leaf.

4 ___

The fiery caterpillar hunter searches for caterpillars on the ground and on tree trunks. Its jaws are adapted for grabbing a caterpillar and tearing through its skin.



5 ___

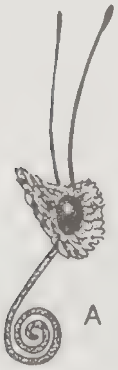
Some termites have nozzlelike mouthparts that shoot out sticky thread onto an insect enemy. The enemy becomes tangled in the threads. The mouthparts of these termites are so well adapted for defense that these termites are unable to feed themselves.

6 ___

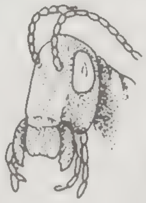
Butterflies sip nectar from flowers. A butterfly's mouth is like a long, flexible straw, which it uses to reach deep into the centers of flowers. When not in use, the tube is coiled up.

7 ___

Houseflies soak up sugarwater with spongelike mouthparts.



A



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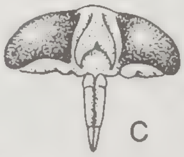

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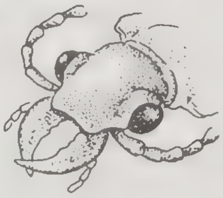

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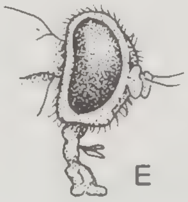
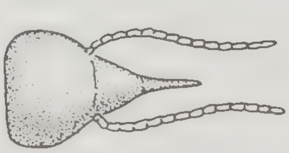


E



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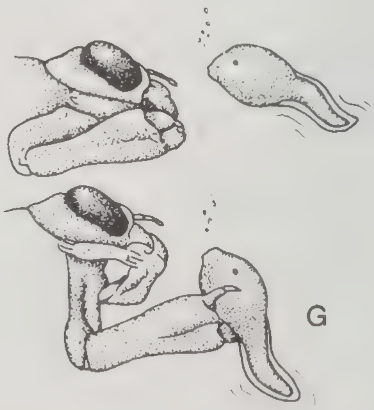


G

Worksheet D: Insect Legs and Locomotion Name:

Insect legs are specialized for various functions. Match each statement below with the insect it describes.

___ 1. This is a blood-sucking parasite of bats. Its six strong legs with claws on the ends are adapted for gripping tightly onto the hairs on a bat's body.

___ 2. The hind legs of this insect are designed for jumping; the front legs are designed for walking.

___ 3. This adult insect has rather unspecialized legs that are used only for walking.

___ 4. This predator swims underwater, searching for small fish and aquatic insects. Its hairy rear legs act like paddles.

___ 5. This larva inches along on the underside of leaves and twigs. First it moves the front half of its body forward; then the back half of its body follows. Its rear legs are like suction cups. It has no legs in the middle part of its body.

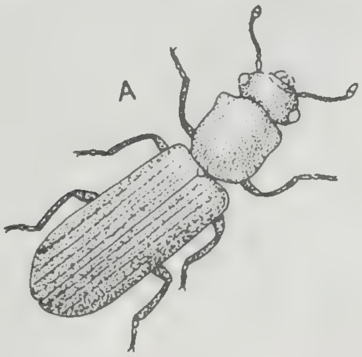
___ 6. This leaf-eating insect must hold tightly to the foliage of its host tomato plant. Its thick, short legs along the length of its body help it to cling to the leaves and stems of the plant.

___ 7. All six legs of this tiny insect are designed for jumping. Its femurs are thick because of the strong leg muscles inside.

___ 8. This insect predator searches for prey on the surface of water. Tiny waterproof hairs on its feet prevent it from sinking.

___ 9. This insect has two legs adapted for hanging and four legs adapted for catching insect prey.

___ 10. This insect has specialized front legs for digging tunnels through soil.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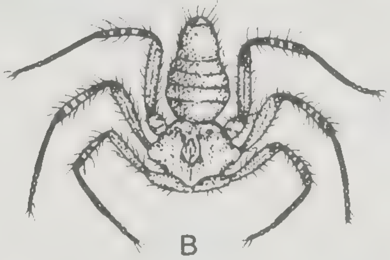
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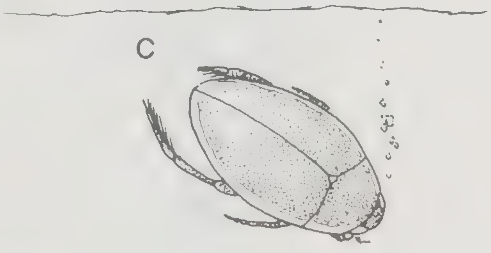
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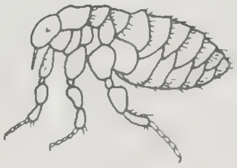
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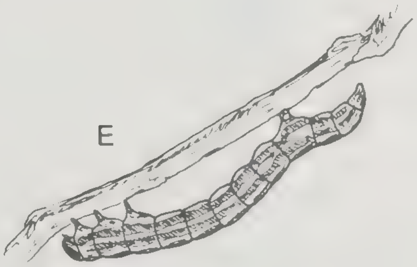
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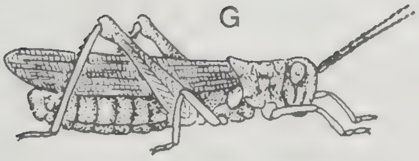
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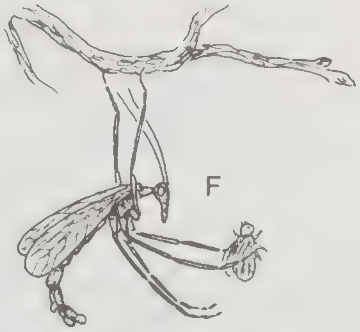
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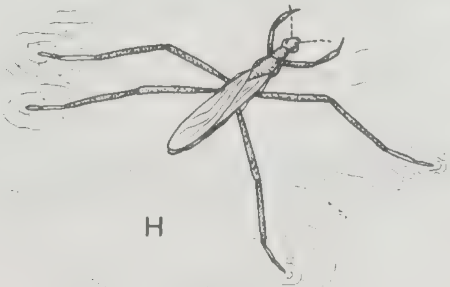
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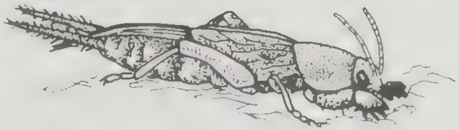
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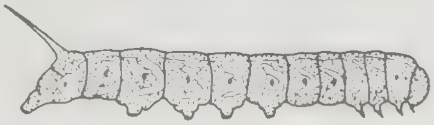
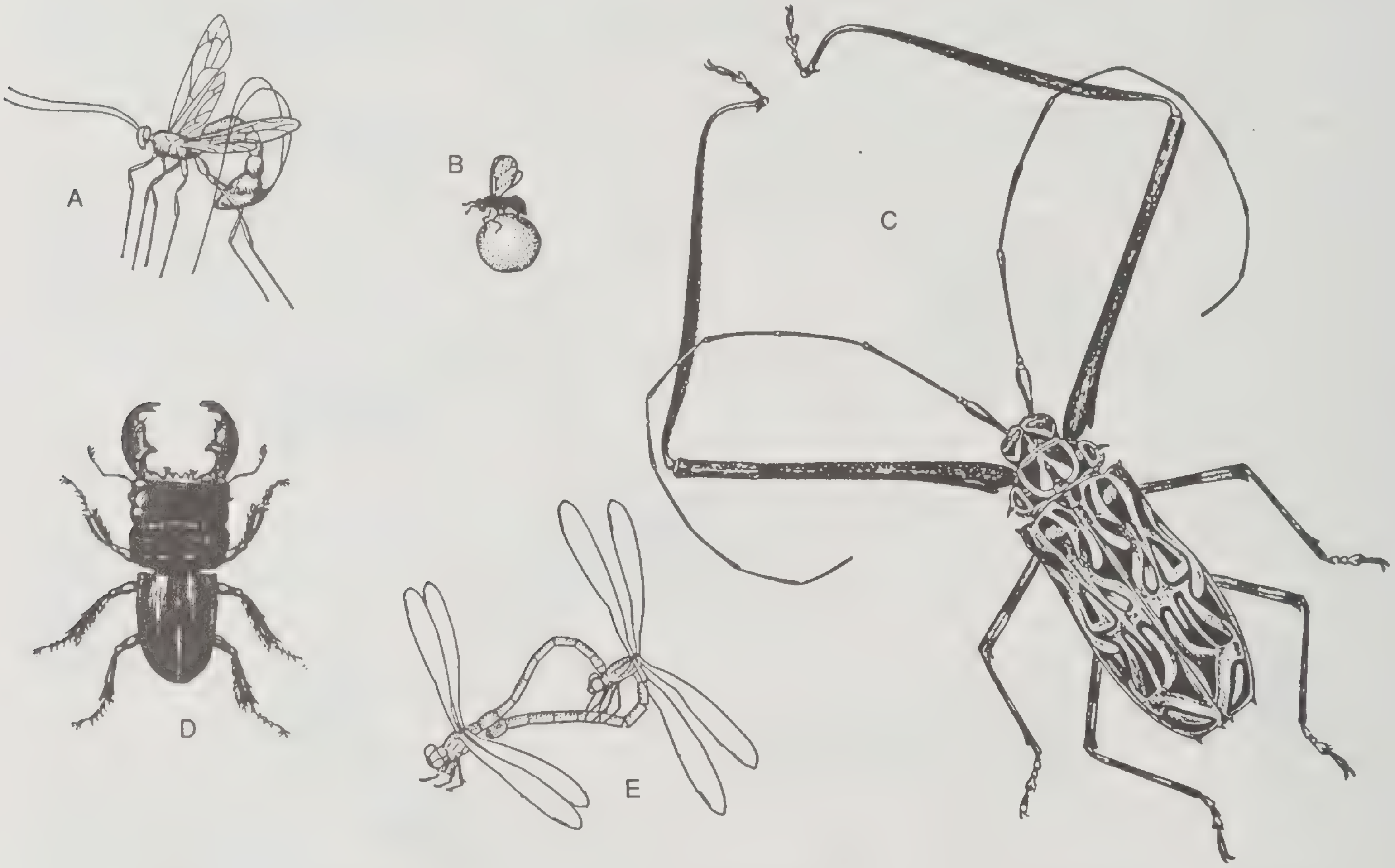

J

Worksheet E: Mating and Egg Laying Name:

In addition to providing physical protection, an insect's tough exoskeleton can include specialized mating and egg-laying structures. Males of certain species have special appendages that help them to be more successful at mating. Female insects use their ovipositors (egg-laying structures) to lay eggs on or near a food source.

Match each of the following pictures with the statement that accurately describes the insect's specialized structure or habits.



___ 1. This tiny parasitic wasp lays its egg in the egg of a gypsy moth. Its ovipositor, therefore, must be strong enough to pierce the shell of the gypsy moth's egg.

___ 2. The male harlequin beetle uses its two front legs to hold onto the female during mating.

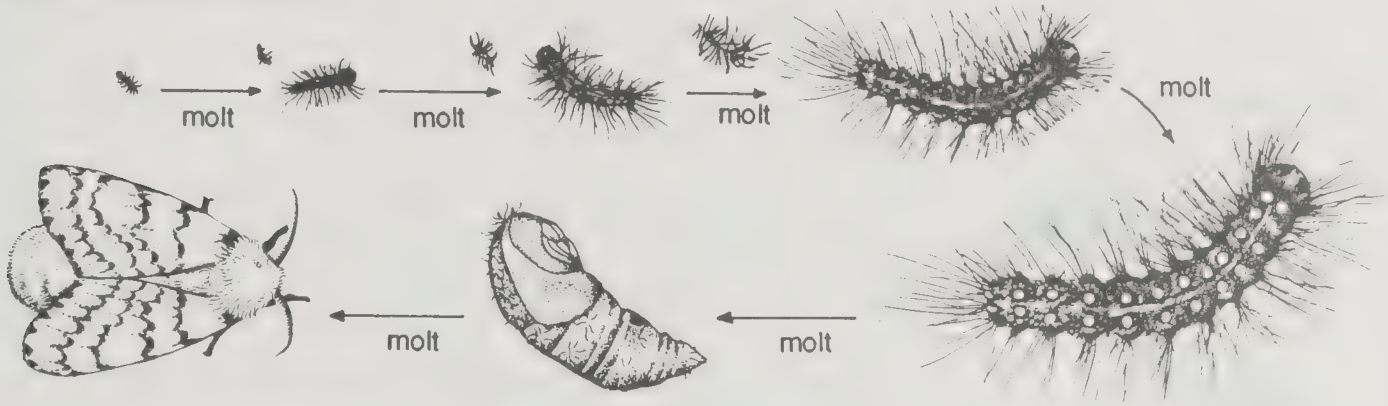
___ 3. The male stag beetle uses its "horns" to fight with other males of its species to win a chance to mate with females.

___ 4. This little wasp lays its eggs in the larvae of beetles inside tree trunks. Its long ovipositor can become rigid enough to push through more than 1/2 inch of wood.

___ 5. Damselflies mate while in flight. The male grasps the female behind her head with the tip of his abdomen. The female collects sperm by placing the tip of her abdomen near the male's sex organs on the anterior (front) end of his abdomen.

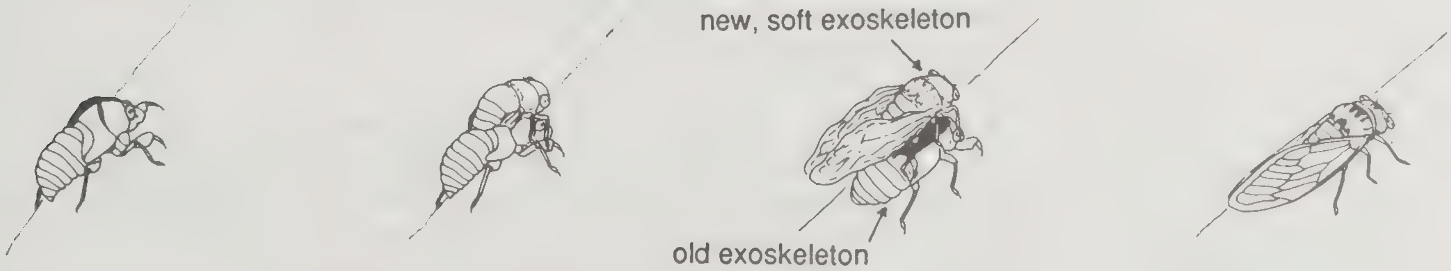
Worksheet F: Molting Name:

Insect exoskeletons come in a variety of shapes, textures, and colors and are well adapted for feeding, protection, mating, walking, egg-laying, and other activities. These hard, protective exoskeleton, however, cannot expand as insects grow. Insects solve this problem by shedding old exoskeletons and replacing them with new, larger ones. This process is called molting. After insects have reached the adult stage, they no longer grow.



The caterpillar or larva of the gypsy moth molts several times. Size is an advantage because a large caterpillar becomes a large adult that lays more eggs than a smaller adult. How many molts does a gypsy moth undergo? ____ What type of metamorphosis does it experience? __________

When an insect is ready to molt, it grows a new, soft, folded exoskeleton just inside the old exoskeleton. Then the old exoskeleton splits, and the insect pulls itself out. Although the new, larger exoskeleton is soft at first, it hardens in a few hours. From Worksheet B, you learned that an insect's exoskeleton supplies support and connections for its muscles. Why must the exoskeleton harden before an insect can fly away or move quickly?



In the late summer you can find the old exoskeletons of cicadas on tree trunks. If you find one, look for the split along its back where the adult cicada crawled out. The cicada does not have a pupal stage; it undergoes simple metamorphosis. Both nymphs and adults suck juices from plants.

Write a short essay in which you compare the molting of an insect such as the cicada with your need to purchase larger shoes as you grow.

6.B Stages of Insect Development

OBJECTIVE to review the stages of insect development

SKILLS/PROCESSES analysis, comparison, identification, sequencing

MATERIALS multiple copies of **Species Development: Fly and Grasshopper** and **Species Development: Gypsy Moth and Squash Bug**

PROCEDURE

1. Review the activities that occur during each of the four stages of general insect development:

   Egg: reproductive product, development of embryo
   Larva or nymph: eating, molting, growing larger
   Pupa: changing from larval form to adult
   Adult: reproduction, eating for maintenance, no further growth

2. Discuss or review simple and complete metamorphosis (Section 6: Background Information).

3. Distribute the **Species Development Sheets** to each student. Students should complete these individually and without reference to their notes or other materials.

4. When the worksheets are completed, you may wish to discuss the answers with the class or to evalute each student's work individually.

EVALUATION If you did not elect to evaluate student performance on the worksheets, you may adapt either of the following activities as an evaluation exercise.

1. If students completed Activity 1.B, ask them to classify the insects displayed on the bulletin board into two categories: those that undergo simple metamorphosis and those that experience complete metamorphosis.

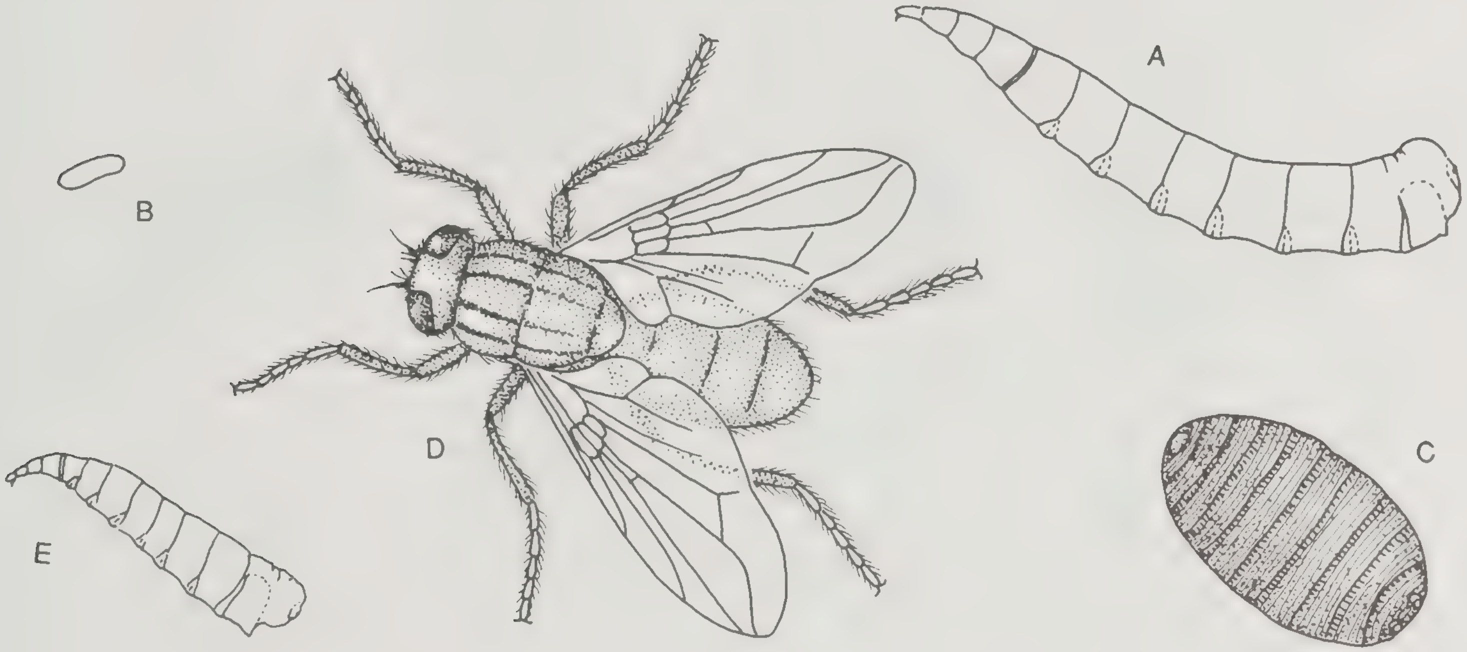
2. Ask students to determine whether the insects included in their library research reports (Activity 5.D) undergo complete or incomplete metamorphosis. Discuss whether or not the type of metamorphosis is characteristic of all insects in a given order.

Species Development: Fly and Grasshopper Name:

1. Write the letters in the order that shows the sequence of development for a fly:

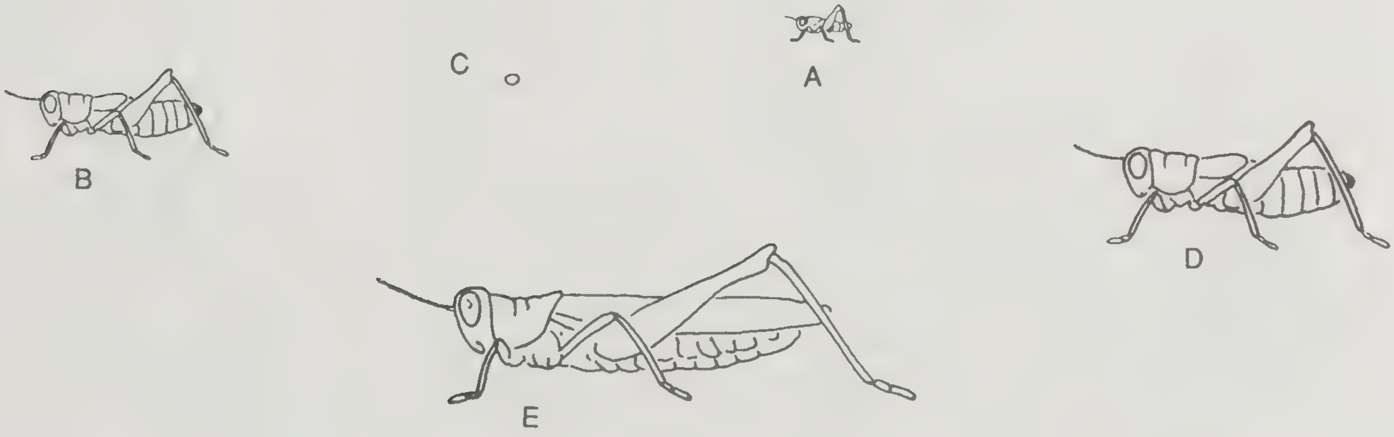
____ ____ ____ ____ ____

2. What type of metamorphosis does the fly undergo? ____________________



3. Write the letters in the order that shows the sequence of development for a grasshopper: ____ ____ ____ ____ ____

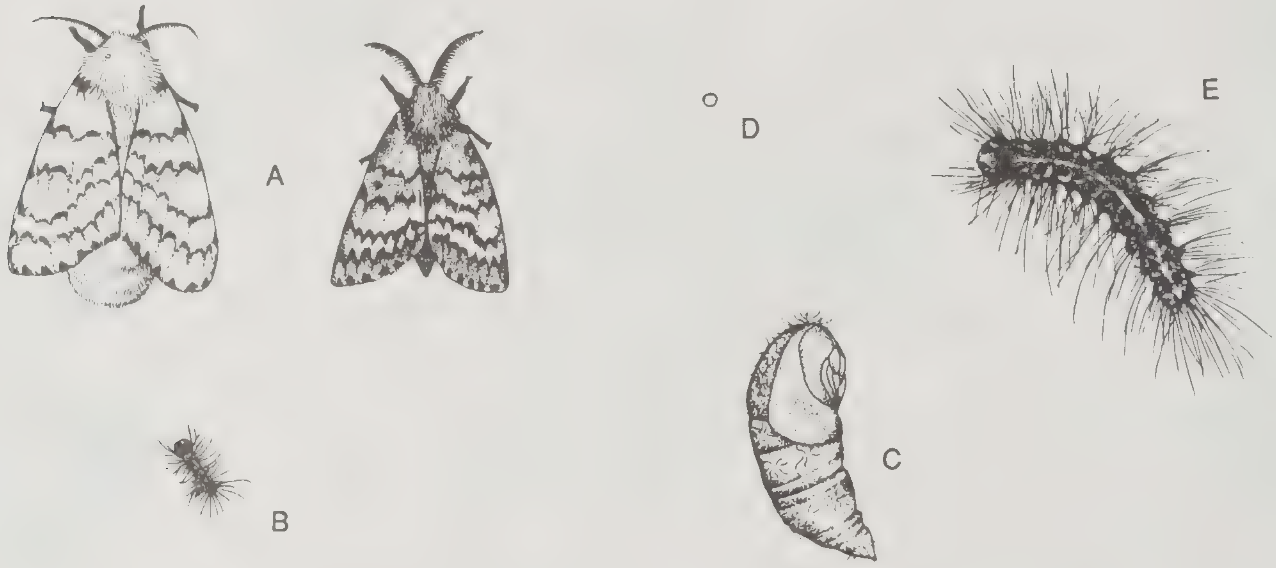
4. What type of metamorphosis does the grasshopper undergo? ____________________



Species Development: Gypsy Moth and Squash Bug Name:

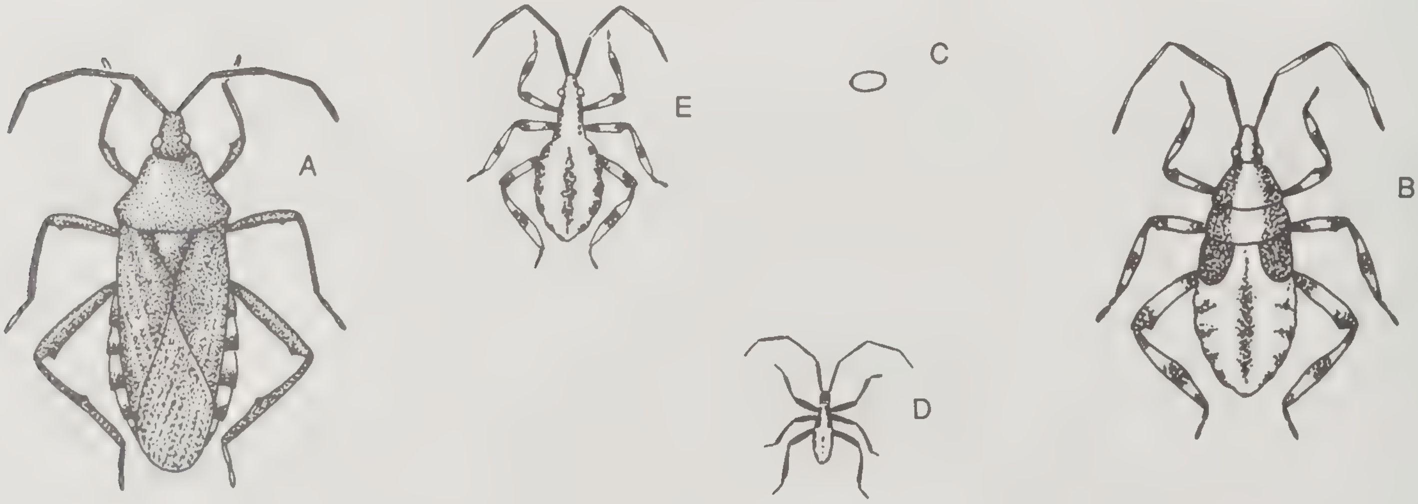
1. Write the letters in the order that shows the sequence of development for a gypsy moth: ____ ____ ____ ____ ____

2. What type of metamorphosis does the gypsy moth undergo? ______________________



3. Write the letters in the order that shows the sequence of development for a squash bug: ____ ____ ____ ____ ____

4. What type of metamorphosis does the squash bug undergo? ______________________



7.

The Gypsy Moth: Background Information

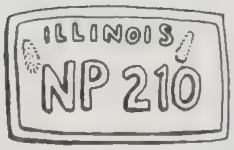
Although its native home is Europe and Asia, the gypsy moth has become a serious forest pest in the United States. It eats the leaves of over 500 species of trees and shrubs and often defoliates trees completely. Although it can cause serious defoliation in its native habitat, outbreaks there are less frequent and of shorter duration than those in the United States because of the many native enemies that use the gypsy moth as a major food resource. These enemies include insects such as predatory beetles and parasitic wasps as well as birds and small mammals. Several diseases found in Europe are specific to the gypsy moth and these also help to keep populations from increasing.

How did the gypsy moth get to the United States in the first place? Leopold Trouvelot, a French scientist working in Medford, Massachusetts, brought the gypsy moth to this country in 1869. He believed that by crossing the European gypsy moth with the silk moth he could develop an improved silk-producing caterpillar. This attempt failed, however, because the moths were of different genera and incapable of mating with each other. Nevertheless, the memory of Trouvelot lives on because some of his research insects escaped. Beginning in 1879, massive outbreaks of gypsy moths were reported in the Medford and Boston areas.

The gypsy moth has become a serious pest in the United States for several reasons. First, it was introduced without its natural checks of predators and disease agents. Second, female gypsy moths lay a tremendous number of eggs—up to 1,000 per female! Third, it was introduced into an area that had an ample supply of food and favorable climatic conditions. With few controls acting on its numbers, gypsy moth populations in the United States have steadily increased.

Since its introduction into the United States, the gypsy moth has spread naturally throughout the northeastern states. The rate of natural dispersal is estimated to be 15 miles per year and depends primarily on the wind. Newly-hatched larvae spin silken threads from which they dangle. Air currents pick up the hairy and buoyant caterpillars, and they hang-glide until deposited at a new location. Not all locations are equally suitable for the larvae, however. Some land on trees and are content, but others find themselves in lakes, on pavement, or splattered on car grills.

Cars and other vehicles cause the demise of a few larvae, but they also help to disperse the gypsy moth. In areas with high gypsy moth populations, female moths will deposit egg masses on any convenient surface, including cars, campers, outdoor furniture, and fireplace logs. When people travel from infested to uninfested areas of the country, these unknown hitchhikers (egg masses and/or pupae) also go along. This method of dispersal is responsible for spot introductions of the gypsy moth into Illinois, Michigan, Oregon, and California.



Gypsy moths spend about three-quarters of their lives in the egg stage. During fall, winter, and early spring each egg within the hairy egg mass is protected from adverse conditions such as drought and cold temperatures, and from predators and parasites.

In the spring, egg hatch is triggered by warm temperatures, and the tiny larvae begin feeding immediately. Adapted for eating and quick growth, gypsy moth larvae are literally "eating machines." Their only protection against predators and parasites is their spiny skin and their habit of feeding on the undersides of leaves. Since the main "occupation" of larvae is to eat and grow, they have no use for reproductive organs and can be considered asexual.

During the pupal stage, gypsy moths rearrange their internal and external structure to become adults. Often referred to as the "resting stage," pupae are actually doing just the opposite. Internally a great change takes place that includes an almost total reorganization of the cells of the insect.

The adult stage is the reproductive or sexual stage of the life cycle. Survival adaptations in this stage are designed to help the moth produce offspring. Male adaptations include strong flight ability and feathery antennae to help locate females; the dark mottled brown coloring helps to deceive predators. Female adaptations include a large abdomen for producing and laying many eggs and glands for producing a male attractant called a pheromone.

What ever happened to Leopold Trouvelot? From all accounts he seems to have returned to his native France and disappeared. Nevertheless, his name lives on in the United States as the man who introduced the gypsy moth.

7.A Life Cycle of the Gypsy Moth

OBJECTIVE

to conceptualize and compute the length of the stages in the life cycle of the gypsy moth

SKILLS /PROCESSES

analysis, calculations, constructing a model, graphing, measuring, using a protractor and compass

VOCABULARY

bar graph, instar, larva (larvae), life cycle, life stage, pie chart, pupa (pupae)

MATERIALS

compasses and protractors
calendar
calculator (optional)
multiple copies of **Life Stages of the Gypsy Moth: Description, Life Stages of the Gypsy Moth: Calculations**, and **Pie Chart/Bar Graph Starter Sheet**

PROCEDURE

1. Distribute **Life Stages of the Gypsy Moth: Description**. Students should read this material carefully before beginning the activity. If you prefer, present this material as a mini-lecture, drawing and labeling each life stage on the chalkboard as you present the sequence.

2. Distribute **Life Stages of the Gypsy Moth: Calculations**. From the information provided there, students determine the percentage of time spent in each life stage; later this data will be used to portray the life stages in a pie chart and bar graph.

3. The guidance you provide will depend on the grade level of your students. They should use a calendar to determine the length of each stage in days. These values will be written in column A. To complete column B, they will need to divide each of these values by 365. For example, the gypsy moth spends 272 days as an egg:

   $$\frac{272}{365} = .7452$$ (the value to be entered in column B)

4. To compute the percentages for column C, students will multiple the values in column B by 100:

   $.7452 \times 100 = 74.52\%$

5. Distribute the **Pie Chart/Bar Graph Starter Sheet** so that students can portray these time relationships graphically.

6. Using the circle at the top of the **Starter Sheet,** students graph the time the gypsy moth spent in each life stage as a pie chart. They will need to multiply the values in column B by 360°.

   .7452 × 360°= 268° (rounded to nearest whole number)

   This value is entered in column D, and tells students that 268° of the 360° that make up a circle indicate the time the gypsy moth spends as an egg. Using a protractor will enable students to complete the pie chart with precision.

7. Students then present the same data in the form of a bar graph.

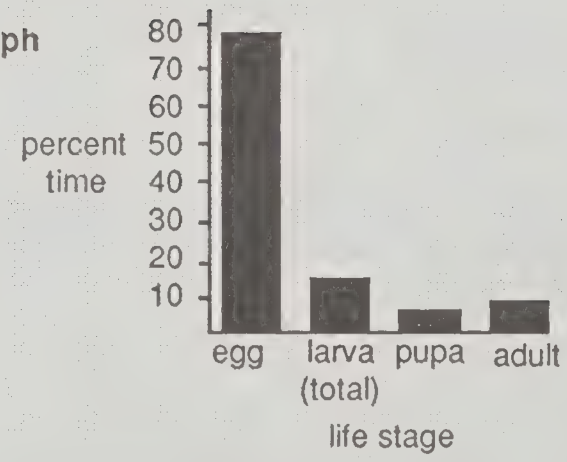
8. An answer sheet is provided below for your reference.

EVALUATION

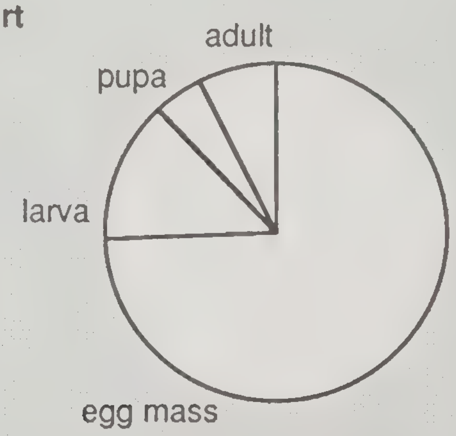
The graphs themselves serve as the evaluation for this activity.

		A	B	C	D
life stage	date	total no. days each stage	proportion of time in each stage	percent of time	degrees
egg mass deposited	Aug. 15	272	.7452	74.52	268
larvae hatch	May 15				
1st molt	May 25	10			
2nd molt	June 2	8			
3rd molt	June 14	12			
4th molt	June 24	10			
ready to pupate	July 3	10			
	total days as larvae:	50	.1370	13.70	49
larvae become pupae	July 3				
adult moths emerge	July 20	17	.0466	4.66	17
adult moths die	Aug. 26	26	.0712	7.12	26

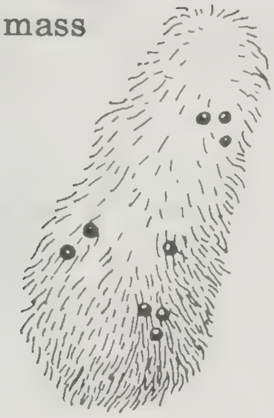
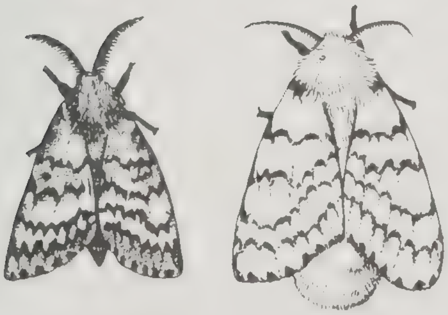
Bar Graph



Pie Chart

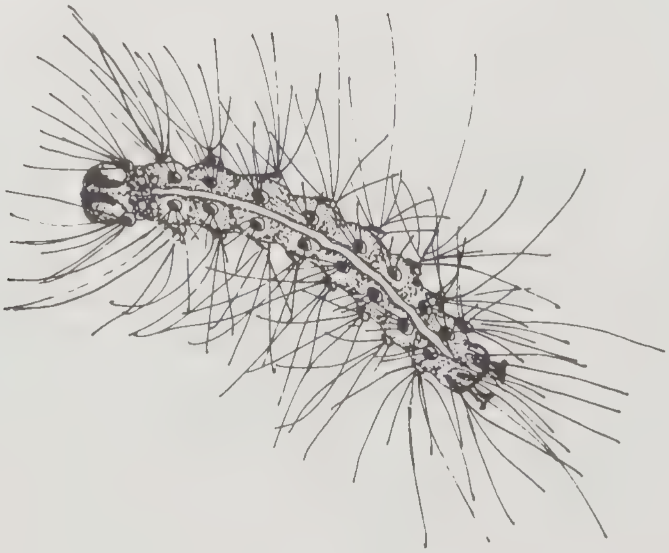


Life Stages of the Gypsy Moth: Description

Life Stage	**Facts and Description**
Egg mass 	The egg mass contains 75–1000 eggs and is covered by velvety brown hairs from the female's abdomen. The eggs survive cold winters in the egg mass.
Larva 	After the larvae (caterpillars) hatch, they soon start the search for food. As they eat more and more leaves, they must shed their old skins to provide room for their growing bodies. The length of time between the molts (the shedding of old skins) is called an **instar**. Gypsy moths experience five instars; that is, they shed their old skins five times. All the larvae do is eat.
Pupa 	The pupa is a brown hardened shell inside which much activity takes place. All the cells and tissues of the gypsy moth are busy reorganizing to build an adult insect.
Adult 	After pupal reorganization is complete, the adult insect crawls out of the pupal shell. At first its wings are small and wrinkled, but as blood is pumped into them, they expand and stiffen. The female moth is large and white and has an abdomen full of eggs. She cannot fly or eat. After mating, the female lays a single egg mass. The male moth is light brown and flies well.

Life Stages of the Gypsy Moth: Calculations Name:

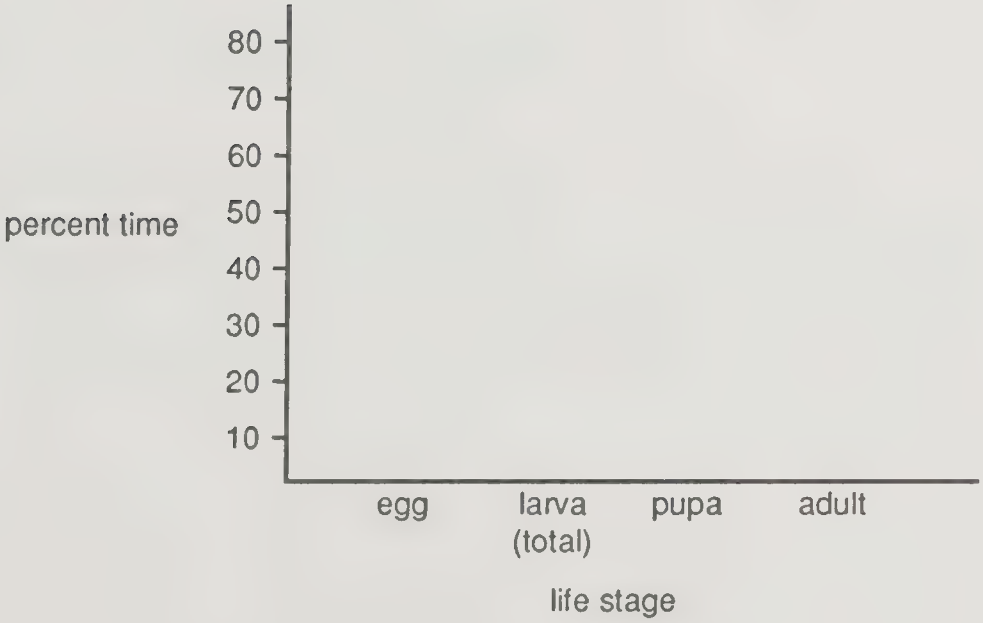
		A	B	C	D
life stage	date	total no. days each stage	proportion of time in each stage	percent of time	degrees
egg mass deposited	Aug. 15				
larvae hatch	May 15				
1st molt	May 25				
2nd molt	June 2				
3rd molt	June 14				
4th molt	June 24				
ready to pupate	July 3				
	total days as larvae:				
larvae become pupae	July 3				
adult moths emerge	July 20				
adult moths die	Aug. 26				



Pie Chart/Bar Graph Starter Sheet Name:

Pie Chart

Bar Graph



7.B What is a Pest?

OBJECTIVE	to develop a definition for the word "pest"
SKILLS/PROCESSES	generalization, classification, application, value judgments
VOCABULARY	pest, pesticide

PROCEDURE

1. Divide a section of the chalkboard into three columns. Label the column to your left "Pests"; label the center column "Reasons"; leave the third column unlabeled at this time. Ask the class to name insects that are pests; list these in the column to the left. As each insect pest is named, ask why we consider it to be a pest. Probe for as many reasons as students can provide, and encourage them to be specific. Write these reasons in the center column.

2. Ask for the names of animals other than insects that are pests. Add these along with specific reasons to the columns on the chalkboard.

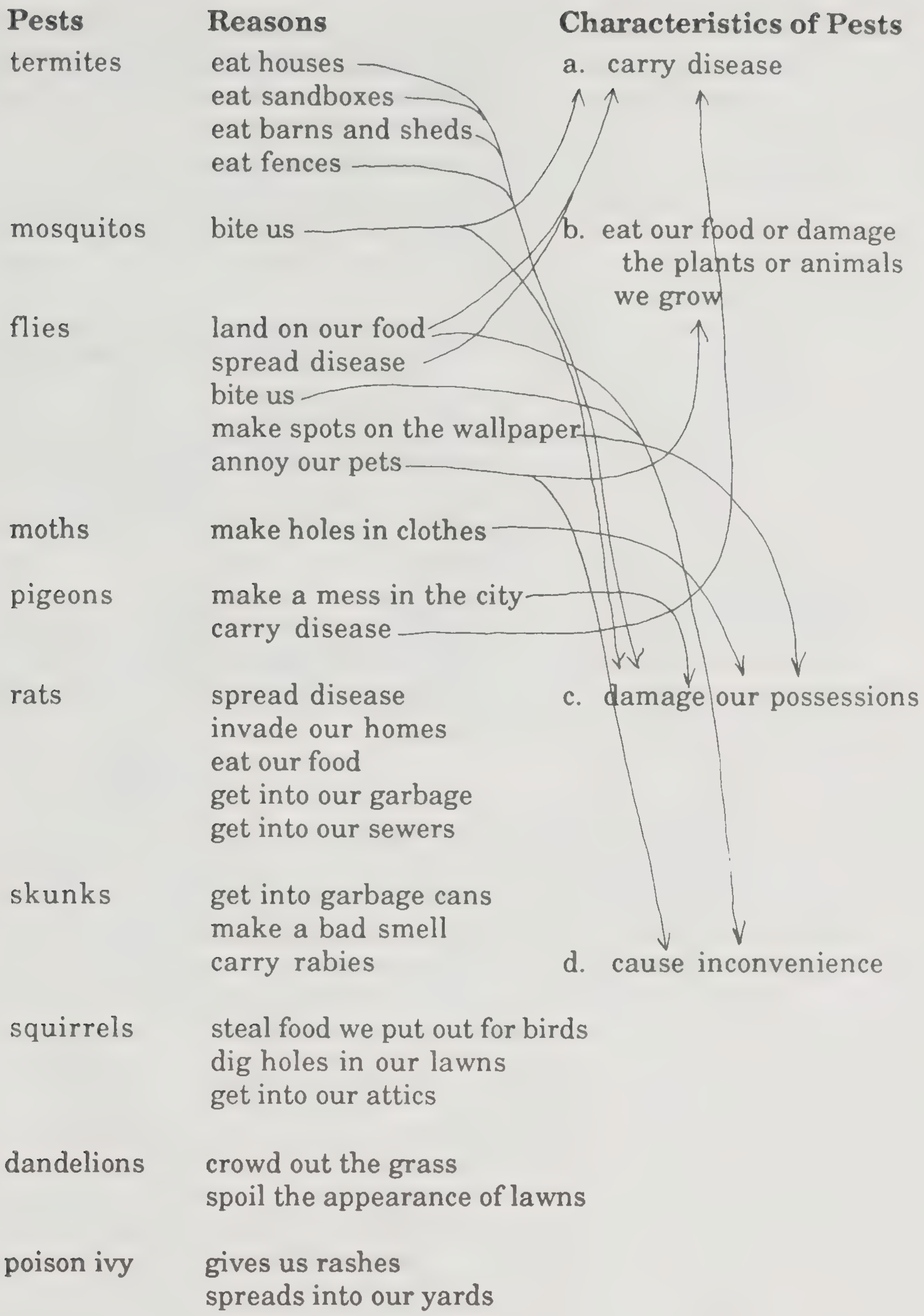
3. Ask for the names of plants that are pests and add these, along with justifications, to the lists on the chalkboard.

4. Review with the class the column of reasons and ask them to define general categories into which those reasons might be sorted. These categories will depend upon the list of reasons, but they will probably include the following four in one version or another:

   a. Carry disease
   b. Eat our food or damage the plants or animals we grow
   c. Damage our possessions
   d. Cause inconvenience

   List these general categories in the third column on the chalkboard, and head the column "Characteristics of Pests."

5. Working together, assign each reason in the center column to one of the characteristics in the column on the right by drawing an arrow from left to right. The following abbreviated example indicates the kinds of responses you can expect.



Pests	Reasons	Characteristics of Pests
termites	eat houses	a. carry disease
	eat sandboxes	
	eat barns and sheds	
	eat fences	
mosquitos	bite us	b. eat our food or damage the plants or animals we grow
flies	land on our food	
	spread disease	
	bite us	
	make spots on the wallpaper	
	annoy our pets	
moths	make holes in clothes	
pigeons	make a mess in the city	
	carry disease	
rats	spread disease	c. damage our possessions
	invade our homes	
	eat our food	
	get into our garbage	
	get into our sewers	
skunks	get into garbage cans	
	make a bad smell	
	carry rabies	d. cause inconvenience
squirrels	steal food we put out for birds	
	dig holes in our lawns	
	get into our attics	
dandelions	crowd out the grass	
	spoil the appearance of lawns	
poison ivy	gives us rashes	
	spreads into our yards	

6. Ask students to name some insects that they do not consider to be pests and to explain why these are not pests. Ladybugs, dragonflies, butterflies, and honeybees are likely to be named. Repeat for animals other than insects and for plants. Be sure to ask students to explain why they do not consider these to be pests.

7. Ask each student to define a pest on a slip of paper. You may collect these or ask for volunteers to read their definitions. In either case, decide on a class definition of a pest. Whatever the particulars of that definition, be sure students realize that organisms are pests only when they interfere with us in some manner. A mouse in the house is a pest, but mice in the meadows are not. A flour beetle in the pantry is a pest, but beetles outside may not be.

8. Which pests listed on the chalkboard are pests sometimes and not at other times? Under what circumstances are they pests?

9. Conclude the activity by discussing briefly the ethics of pest control and pesticides. When should pesticides be used? How much "damage" is acceptable before we resort to the use of poisons? Subsequent activities will explore various types of pest control.

EVALUATION

Give students five minutes to write an answer to this question: When is a pest not a pest? Request that their answers include reference to three organisms commonly considered to be pests.

7.C Biogeography

OBJECTIVE

to identify the countries in which the gypsy moth is native and the areas in the United States in which it now occurs

SKILLS/PROCESSES

map reading and plotting

VOCABULARY

biogeography, density, isolated, population, spot introductions

MATERIALS

multiple copies of the map of **Europe, Asia, and Africa,** the map of the **United States,** and the **Data Sheet: Gypsy Moth Populations in the United States**
colored pencils

COMMENTS

Gypsy moths were introduced into Massachusetts in 1869 and now commonly occur within 14 states. Gypsy moths have also been found in isolated areas of 6 midwestern and western states. These areas are referred to as **spot introductions** and are a direct result of human dispersal of the gypsy moth. Section 7: Background Information provides a basis for the discussion at the end of this activity.

PROCEDURE

1. Distribute copies of the map of **Europe, Asia, and Africa.** Students identify as many of the countries in which the gypsy moth is native as they can by matching the numbers on the map with the countries listed there. Check the answers together, using a map or globe as a reference or by resorting to the answer key below. Complete the activity by asking students to color the countries in which the gypsy moth is native.

   Answer Key: Native Countries of the Gypsy Moth

   1 Portugal
   2 Albania
   3 India
   4 Czechoslovakia
   5 Korea
   6 Poland
   7 Morocco
   8 Rumania
   9 China
   10 Austria
   11 Hungary
   12 Spain
   13 Greece
   14 Bulgaria
   15 Iran
   16 Japan
   17 Tunisia
   18 Yugoslavia
   19 Turkey
   20 Soviet Union

2. Distribute copies of the **Data Sheet** and the map of the **United States.** Students color in the states listed on the **Data Sheet.** They should use three colors to indicate the population density levels. Spot introductions may be shown by a dot or star of a fourth color in the infested area of the state.

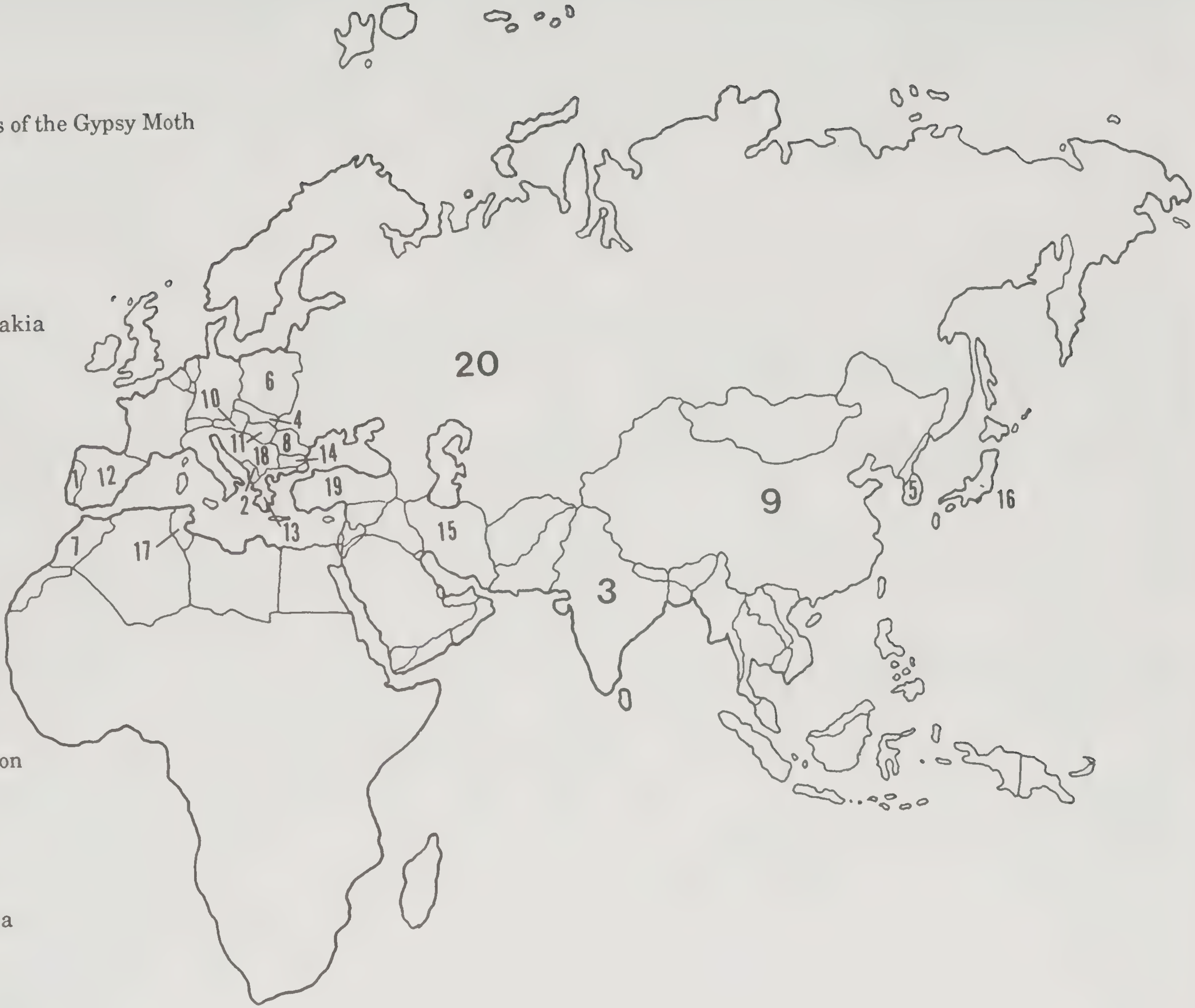
3. When the maps are complete, discuss the pattern of distribution that is seen in the United States. What do the spot introductions suggest? What suggestions do students have for how these isolated introductions occurred?

4. Use some or all of the maps for a bulletin board display, or if there is time, distribute large sheets of paper and glue or cellophane tape so students can use their pairs of maps to to make posters. Encourage them to come up with individual titles and labels. You may wish to introduce the term **biogeography**.

EVALUATION

Evaluate the success of this activity by examining the maps or posters.

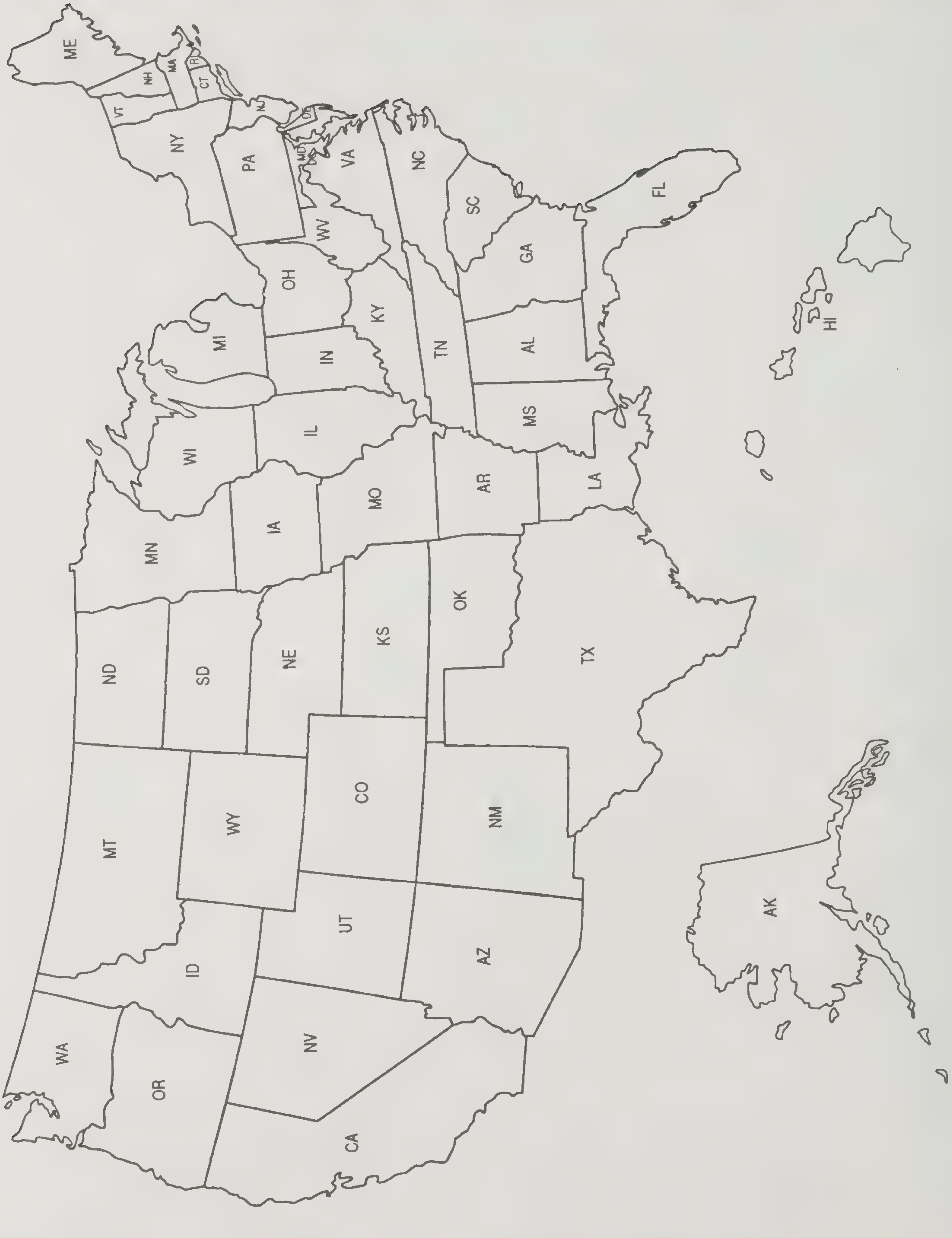
Europe, Asia, and Africa Name:



Native Countries of the Gypsy Moth

___ Albania
___ Austria
___ Bulgaria
___ China
___ Czechoslovakia
___ Greece
___ Hungary
___ India
___ Iran
___ Japan
___ Korea
___ Morocco
___ Poland
___ Portugal
___ Rumania
___ Soviet Union
___ Spain
___ Tunisia
___ Turkey
___ Yugoslavia

United States Name:



States with Widespread Gypsy Moth Populations	Population Density of Gypsy Moths
Connecticut (CT)	High
Massachusetts (MA)	High
New Jersey (NJ)	High
New York (NY)	High
Pennsylvania (PA)	High
Delaware (DE)	Medium
Maryland (MD)	Medium
Michigan (MI)	Medium
Maine (ME)	Low
New Hampshire (NH)	Low
Ohio (OH)	Low
Vermont (VT)	Low
Virginia (VA)	Low
West Virginia (WV)	Low

Isolated Areas Where Gypsy Moths Have Been Found (Spot Introductions)

State	Area of state
Illinois (IL)	Northeast
Indiana (IN)	Southwest
Oregon (OR)	Northwest
Washington (WA)	South
Wisconsin (WI)	North Central
Minnesota (MN)	Southeast

7.D Why Is the Gypsy Moth a Pest?

OBJECTIVE	to understand the biological reasons for classifying the gypsy moth as a pest in the United States
SKILLS/PROCESSES	interpretation, synthesis, application, written communication
VOCABULARY	outbreak, reproductive potential
MATERIALS	multiple copies of **Descriptions of the Gypsy Moth Outbreak of 1889 in Medford, Massachusetts 1** and **2** crayons or colored pencils

PROCEDURE

1. Tell the class the story of how the gypsy moth was introduced into the United States. Use the material given in the Background Information of this section. In addition, point out that each of the escaped female moths probably laid about 500 eggs. These eggs hatched the following spring, and most of the caterpillars survived throughout the summer, pupated, and emerged as adults ready to mate and lay more eggs. (Remind students of the "doubler" and "tripler" activity they completed earlier, Activity 3.B.) Very few caterpillars died each year because there were no natural controls, and so each new generation was extremely successful. By 1889, twenty years after their introduction, there were too many gypsy moths in Medford.

2. Distribute copies of **Descriptions of the Gypsy Moth Outbreak**. Students read the quotations from an 1896 publication of the Massachusetts Board of Agriculture and choose one to illustrate as completely as possible based on the information in the quotation.

3. Share the pictures by making a booklet or a bulletin board display. Pictures may be mounted on construction paper with the matching quotation.

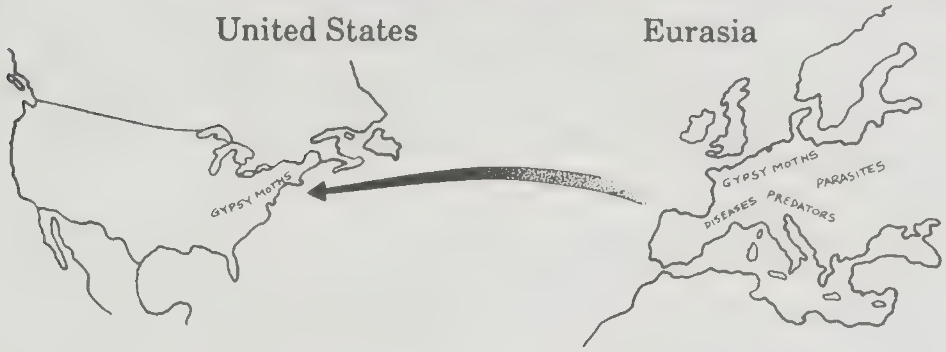
4. Discuss questions such as these: Were gypsy moths a pest in Massachusetts in the early 1800s? Why or why not? Were they a pest in 1889? Why? What lesson is to be learned from what happened in Medford?

5. Introduce the following three biological reasons that explain why the gypsy moth is such a destructive pest in the United States and why it is not as great a pest in its native home of Europe and Asia. These reasons hold true for all regions of the United States that are infested with gypsy moths today. You may elect to present this material as a "chalkboard lecture" or you may wish to make and distribute copies of the following information, especially if your students are keeping insect notebooks.

Why Has the Gypsy Moth Proved So Destructive in the United States?

- Lack of predators, diseases, and parasites

When the gypsy moth was introduced into Massachusetts in 1869, its predators, diseases, and parasites were left behind in Eurasia. These organisms help to regulate gypsy moth numbers in Europe and Asia but are not found in the United States. Thus the gypsy moth reproduced each year without the loss of many offspring.



- Great reproductive potential

Gypsy moths have a tremendous reproductive potential. The eggs are laid in a mass that is protected with a covering of hairs from the female's body. The female moth usually lays her eggs in protected sites on trees or on such objects as cars and houses. Recall how fast the bean numbers grew in the "doublers/triplers" activity, and bear in mind that a single gypsy moth can lay as many as 1,000 eggs! The progeny from a female that laid 400 eggs the first year is shown below.

Generation (one generation per year)	Population Size
1	400
2	80,000
3	16,000,000
10	204,800,000,000,000,000,000,000

- Unlimited food supply

Oaks are a major component of forests in the eastern United States, and the leaves of this tree are a favorite food of the gypsy moth. The offspring of each generation of gypsy moths found great expanses of food and therefore reproduced at peak efficiency.

EVALUATION

Each student writes a paragraph summarizing why gypsy moths are a pest in the United States but less of a pest in Europe and Asia. If you have been working on paragraph development, you may want the class to develop together a topic sentence to govern this paragraph, one that each student can then use or modify. This assignment also provides an opportunity to introduce words and phrases of transition and contrast: *therefore, consequently, however, on the other hand, in contrast, as a result, as opposed to.*

Descriptions of the Gypsy Moth Outbreak of 1889 in Medford, Massachusetts [1]

Choose one of the following paragraphs and draw a picture that illustrates what the paragraph describes. Include as many specific details as you can.

"There was a beautiful maple on the street in front of the next house, and all its leaves were eaten by the caterpillars. They got from the ground up on the house and blackened the front of it. I spent much time in killing caterpillars. I used to sweep them off the side of the house and get dustpanfuls of them. . . . In the morning the walk would be covered with [their excrement]."

"Prominent citizens have testified that the 'worms' were so numerous that one could slide on the crushed bodies on the sidewalks; and that they crowded each other off the trees and gathered in masses on the ground, fences, and houses, entering windows, destroying flowering plants in the houses, and even appearing in the chambers at night. The myriads that were crushed under foot on the sidewalks of the village gave the streets a filthy and unclean appearance."

"In another yard two large apple trees were stripped by the caterpillars, and died. The way this was brought about was as follows: the caterpillars stripped the trees early in the season, and, as they continued their ravages for nearly the whole summer, the trees had no chance to recover. The next year the trees would leaf out and be stripped again, and so on, until, unable longer to withstand such treatment, they died."

"The two large elms in front of our house were full of caterpillars, and had not a perfect leaf. In the nighttime the noise of the worms eating in the trees sounded like two sticks grating against each other. In the months of July and August I have gone out in the morning and raked up from under the elms a pile of leaves three or four feet high. These leaves had been cut off by the caterpillars, and usually there was a worm on the underside of every leaf."

"Another of our neighbors had the whole front of her house practically covered with caterpillars. One could hardly go outdoors without getting caterpillars on the clothing. You could see them travelling about. There were thousands of eggs and caterpillars under the underpinning of the houses. When the caterpillars were very small they would get all over the washing when it was hung out."

"Before caterpillar time we used to see bodies of trees plastered all over, with their egg clusters. They were so thick on certain trees that they reminded me of shells at the seashore. When the caterpillars were small they would spin down on their threads and blow out into the street or even entirely across it. The caterpillars were a dirty pest. Trees were either completely stripped so that not a green thing was to be seen on them, or else were eaten so that the skeletons of the leaves only remained."

Descriptions of the Gypsy Moth Outbreak of 1889 in Medford, Massachusetts 2

"In the summer of 1889, while living on Park Street, Medford, we were literally overrun with the gypsy moth caterpillars. That summer we could have got the caterpillars out of the holes in the trees by pecks. After the caterpillars ate all the leaves off the trees, they went down into the grass, where they swarmed. When the plague was the worst that summer, I do not exaggerate when I say that there was not a place on the outside of the house where you could put your hand without touching the caterpillars. . . . We always tapped the screen doors when we opened them, and the monstrous great creatures would fall down, but in a minute or two would crawl up the side of the house again. When the caterpillars were the thickest on the trees, we could plainly hear the noise of their nibbling at night when all was still. It sounded like the pattering of very fine raindrops. If we walked under the trees we got nothing less than a shower bath of caterpillars. . . . The caterpillars were so thick on the trees that they were stuck together like cold macaroni."

"The moths were so thick at one time under the willows that I have collected them by the handful and fed them to my hens."

"Nothing too bad can be said of the caterpillars. If you sat down anywhere you would crush caterpillars. If the washing was hung out under trees infested with them, they would get on and stain the clean clothes. They were all over the sidewalks, and would drop down upon one from the trees."

"The greenhouse was full of them [caterpillars]. The warmth caused them to hatch out early. I destroyed most of them by picking off the leaves and burning them, and also by spraying with an emulsion of whale-oil soap, kerosene and ammonia."

"The outside of my stable was literally black with caterpillars at the time when the gypsy moth was the thickest in this section. It was a disgusting sight."

"The caterpillars were so thick in the trees that you could hear them eating. They would get on fences, until they made them fairly black. They would crawl up and into houses. They would get inside somehow, and it was a common thing to see them crawling on the table, and we have even found them on the beds. . . . I have seen them crawling in great numbers on the rails of the Medford branch track. After a train had gone along, the rails would be all green with their crushed bodies."

From: E. H. Forbush and C. H. Fernald. 1896. The Gypsy Moth: *Porthetria dispar* (Linn.). Massachusetts Board of Agriculture. Wright & Potter Printing Co., Boston, Mass.

7.E

Find the Gypsy Moth Egg Masses

OBJECTIVE

to identify ways in which humans disperse gypsy moths from infested to uninfested areas of the United States

SKILLS/PROCESSES

visual discrimination, transfer of information

VOCABULARY

dispersal, disperse, infested

MATERIALS

multiple copies of **Hidden Egg Masses**

PROCEDURE

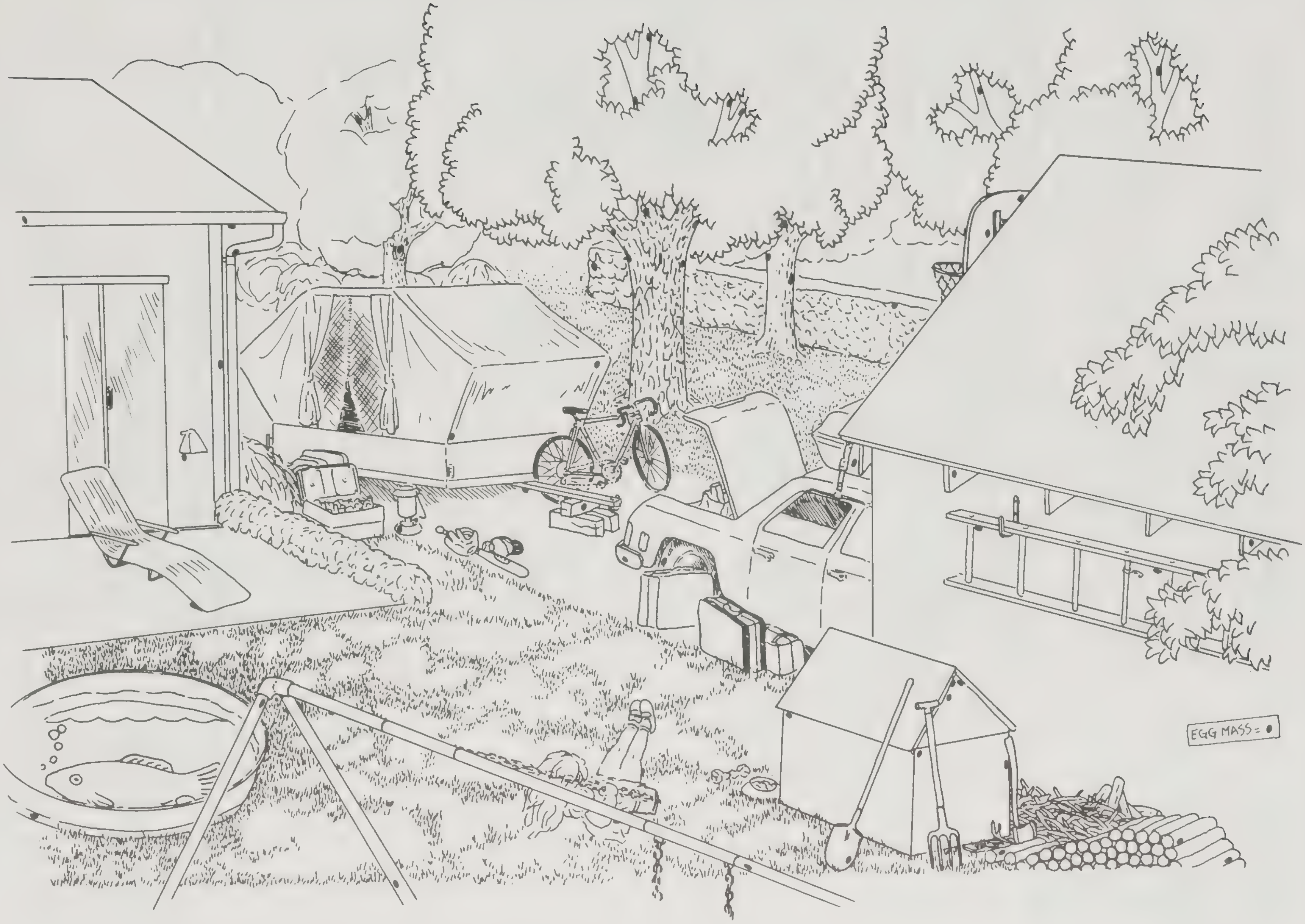
1. Distribute copies of **Hidden Egg Masses**. Each student locates and circles the gypsy moth egg masses shown in the picture. There are fifty egg masses hidden in the picture.

2. Each student then chooses an egg mass and describes orally or in writing how that egg mass might be moved from an infested to an uninfested state. For example, the egg mass laid on the lantern during a camping trip to an infested state park in Massachusetts might be brought back to Illinois when the family returns home after its vacation.

EVALUATION

Students list at least five objects in their homes or garages that might serve as means of transporting gypsy moth egg masses from one area to another. If students wish, they may accompany this list with illustrations of how the egg mass would look on the objects they chose. This list should not include objects that were shown on the work sheet used in class. If there is time, compile a master list on the chalkboard from the student-generated lists.

Hidden Egg Masses Name:



7.F Dispersal by Humans

OBJECTIVE to demonstrate our importance in dispersing gypsy moth eggs from infested to noninfested areas of the country

SKILLS/PROCESSES group participation, role playing

VOCABULARY infested, population density

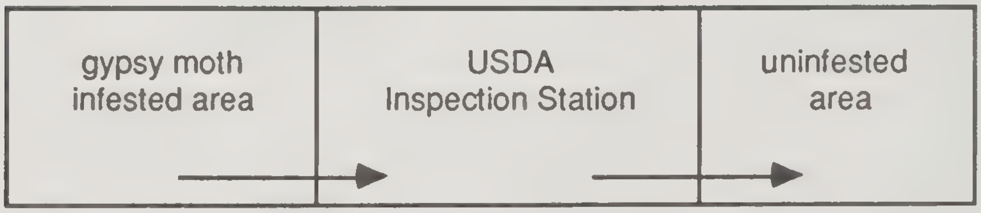
MATERIALS dots from a paper punch

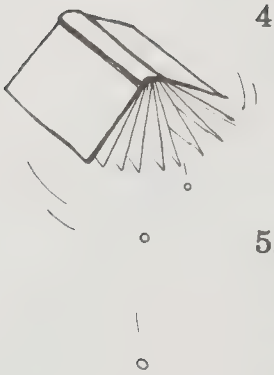
PROCEDURE

1. Before beginning this activity, explain that the United States Department of Agriculture is a federal agency that, among other duties, regulates the transportation of biological materials and organisms between states. One of its jobs is to maintain inspection stations at state borders, an activity that is aimed at preventing accidental importation of such pests as the gypsy moth.

2. Divide the classroom to represent 1) an area infested by gypsy moths, 2) a USDA inspection station, and 3) an uninfested area. Then divide students into three groups to represent a) gypsy moths, b) USDA inspectors, and c) travelers.

3. Give each student-moth 20 paper dots, each of which represents an egg mass, but do not let the travelers or the inspectors know how many dots have been distributed. Then move the student-moths into the "infested" area of the room.

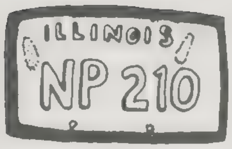




4. Each traveler must pass through the infested area, giving three objects (books, notebooks, lunch bags, pencil cases) to a gypsy moth. The moths have 3 minutes to deposit their egg masses in or on these objects. Neither inspectors nor travelers may watch as the egg masses are hidden.

5. The objects are returned to the travelers, who move on to the inspection station. USDA inspectors have only 1 minute to check the belongings of the travelers and remove any egg masses they find.

6. The inspectors count the number of dots they found, and the travelers move on to their destination—the uninfested part of the room. Upon arrival, they search their possessions for egg masses that were not detected by the inspectors. The assistance of the student-moths may be required if the total number of egg masses is to be retrieved. How many gypsy moth egg masses made it through the inspection station?

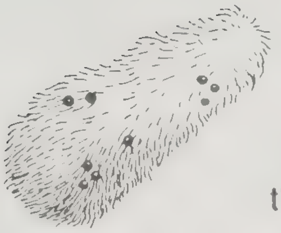


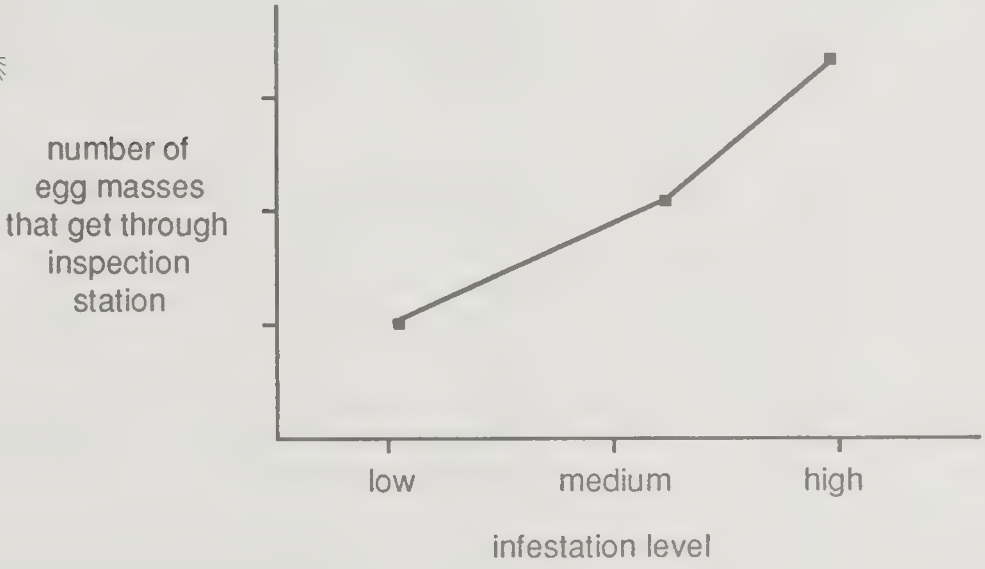
7. Discuss the importance—and the difficulty—of checking for gypsy moth egg masses when vehicles and people move from an infested to an uninfested area. If each egg mass (dot) not collected by the USDA inspectors contained 500 eggs, how many gypsy moths would hatch the following spring?

EVALUATION

Either of the variations described below may be used to evaluate and extend the activity.

Variation A: Assign three infestation levels: low = 10 paper dots, medium = 20 dots, high = 35 dots. These three levels represent three infested areas, each with a different population density of gypsy moths. The USDA inspectors still have only 1 minute to inspect the objects. Determine if the level of infestation affects the number of egg masses that pass undetected through the inspection station. Graph the relationship between the level of infestation and the number of undetected egg masses, as shown below:




number of egg masses that get through inspection station
low
medium
high
infestation level

Variation B: Assign each traveler a departure city in an infested area and a destination city in an area that is uninfested. Mark these on a copy of the map of the United States supplied in Activity 7.C. After the travelers have gone through the inspection station and counted the undetected dots, mark on the map those cities to which the gypsy moth has just been introduced by your travelers.

7.G More about the Life Cycle of the Gypsy Moth

OBJECTIVE

to learn more about factors that affect the survival of the gypsy moth during its various life stages

SKILLS/PROCESSES

social interaction, record keeping, reenforcement of concepts

VOCABULARY

disperse, life stage, mandibles, metamorphosis, parasite, parasitized, pheromone, predator

MATERIALS

For each group of 4–6 students:
- a copy of **Construction Guide**
- a copy of **Components A–D**
- a copy of **Picture Sheets 1–4**
- a piece of cardboard large enough to mount the game board (approximately 22 inches square)
- a copy of **Rules of the Game**
- a die

scissors, glue, and crayons or colored pencils
materials suitable to use as tokens: paper clips, buttons, pennies, shapes cut from cardboard
graph paper
one copy of **Tally Sheet** for each student

PROCEDURE

1. Divide the class into groups of 4–6 students. Distribute the materials so that each group can construct its own game board by coloring, cutting out, and mounting the components and pictures on cardboard.

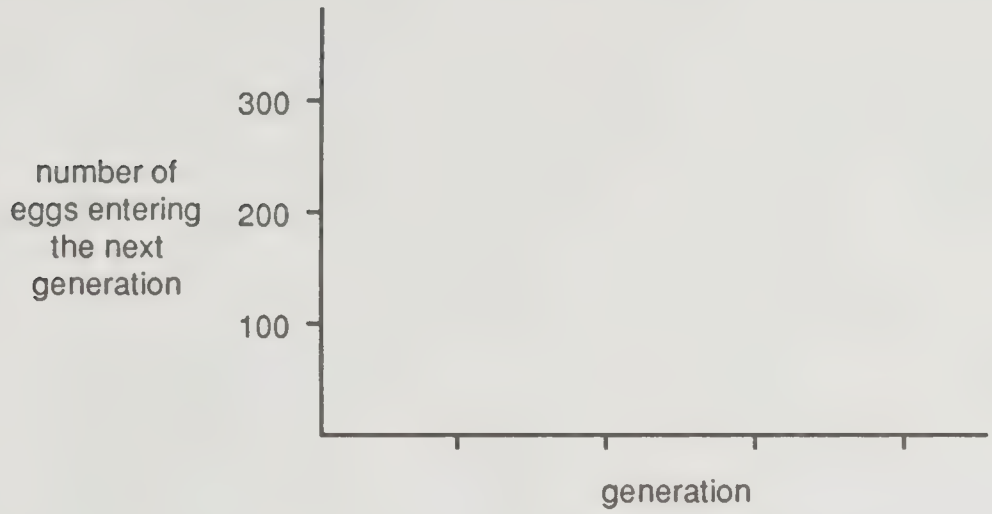
2. Distribute a copy of **Rules of the Game** to each group or explain the **Basic Rules** to the class as a whole.

3. Monitor the play and help any group that has difficulty following the rules.

4. After groups have completed one round of play using the **Basic Rules**, ask them to try the **Advanced Rules**. Distribute a **Tally Sheet** to each student.

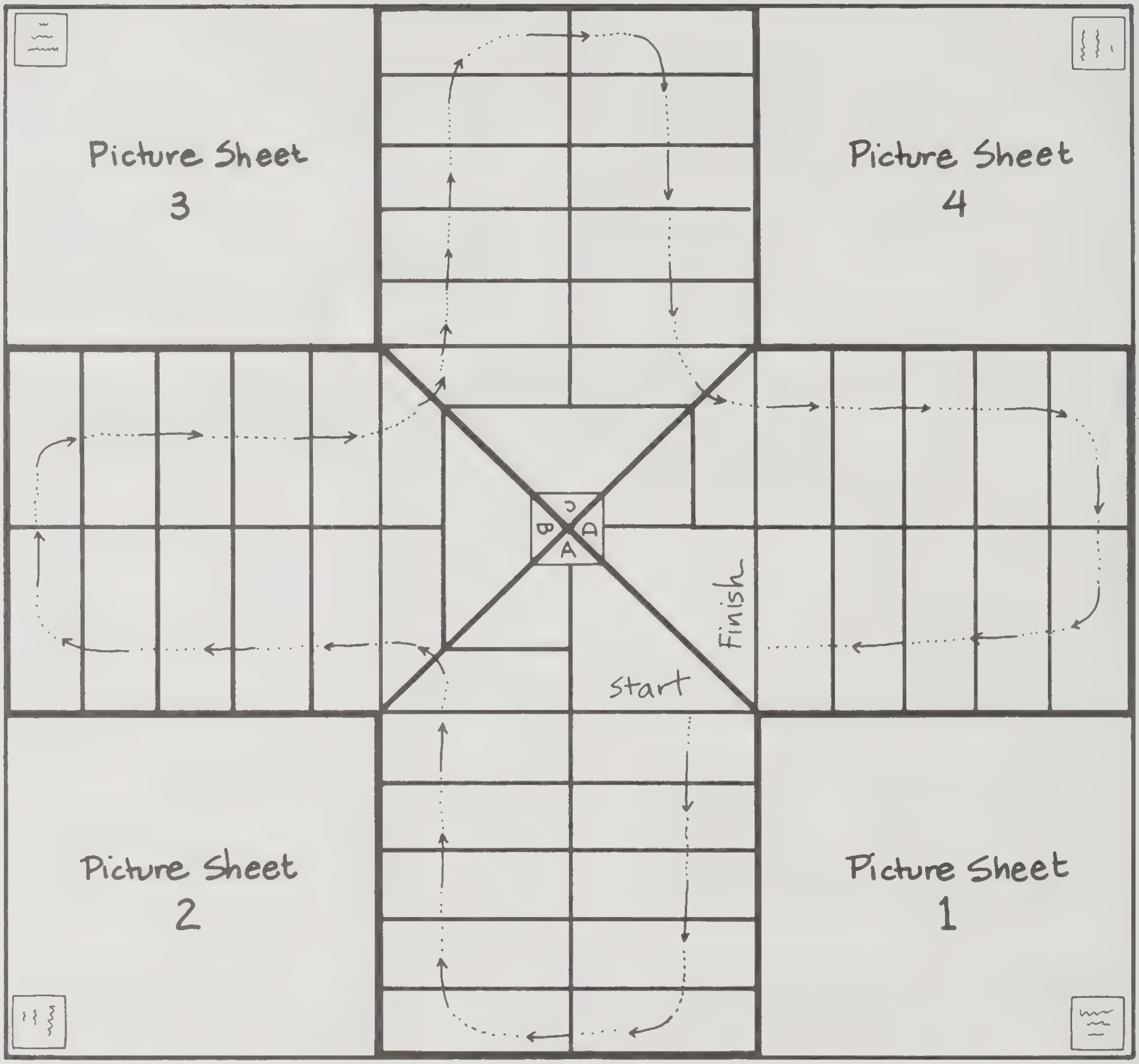
5. Monitor the play and assist any group that has difficulty. When groups have completed three rounds of play and produced three generations of gypsy moths, they graph the population curve on axes similar to those below.

6. Sum all data for the class and graph the total population curve on the chalkboard.



EVALUATION

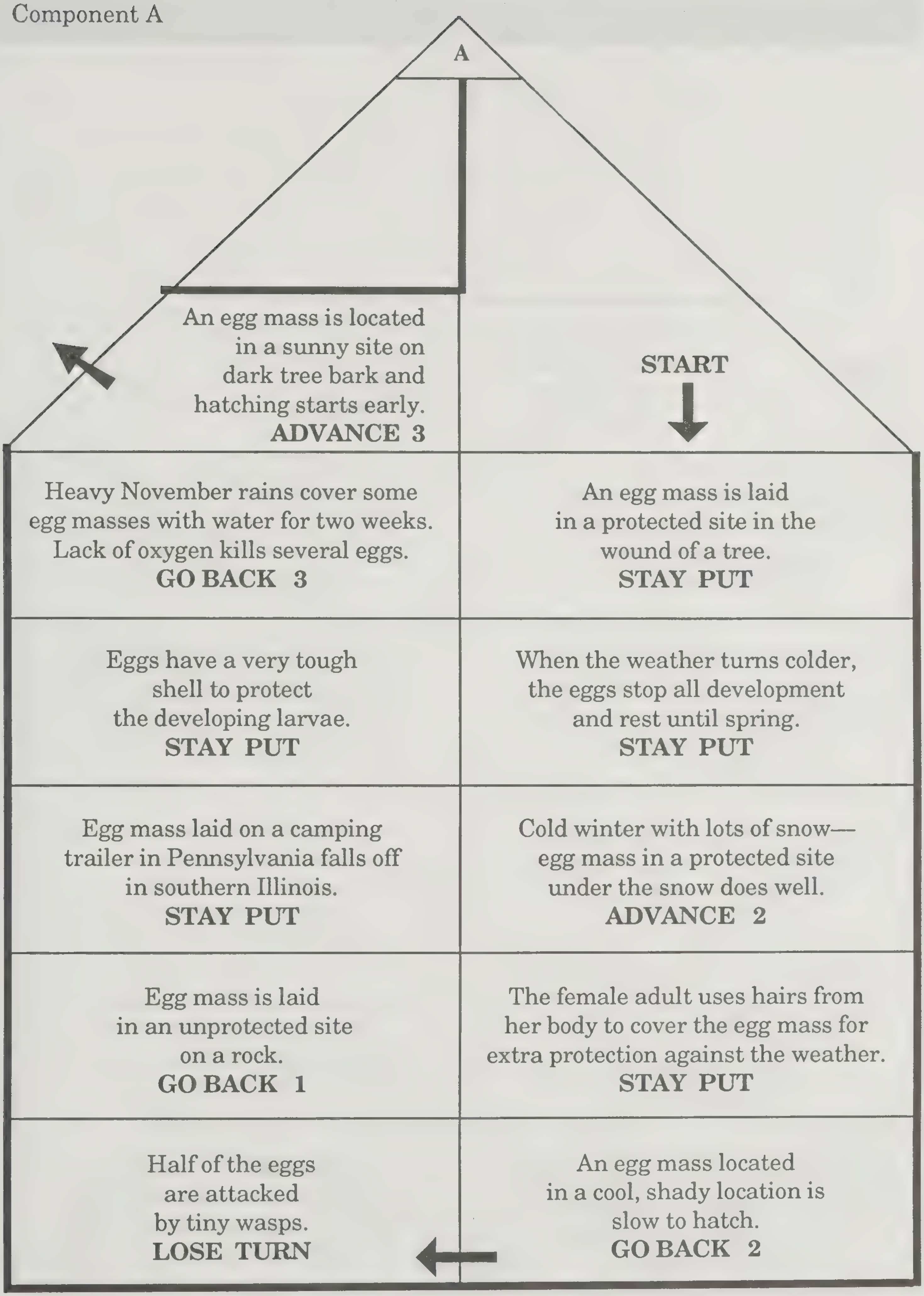
Assign one of the four life stages to each student in a group. Students then locate two positive and two negative factors on the game board that affect gypsy moth survival within the assigned life stage.



1. Cut out components A–D along the dotted lines and paste them on the sheet of cardboard in the arrangement shown above.

2. Cut out pictures 1–4 and paste them in the boxes by following the numbers shown above.

Component A



An egg mass is located in a sunny site on dark tree bark and hatching starts early.
ADVANCE 3

Heavy November rains cover some egg masses with water for two weeks. Lack of oxygen kills several eggs.
GO BACK 3

An egg mass is laid in a protected site in the wound of a tree.
STAY PUT

Eggs have a very tough shell to protect the developing larvae.
STAY PUT

When the weather turns colder, the eggs stop all development and rest until spring.
STAY PUT

Egg mass laid on a camping trailer in Pennsylvania falls off in southern Illinois.
STAY PUT

Cold winter with lots of snow—egg mass in a protected site under the snow does well.
ADVANCE 2

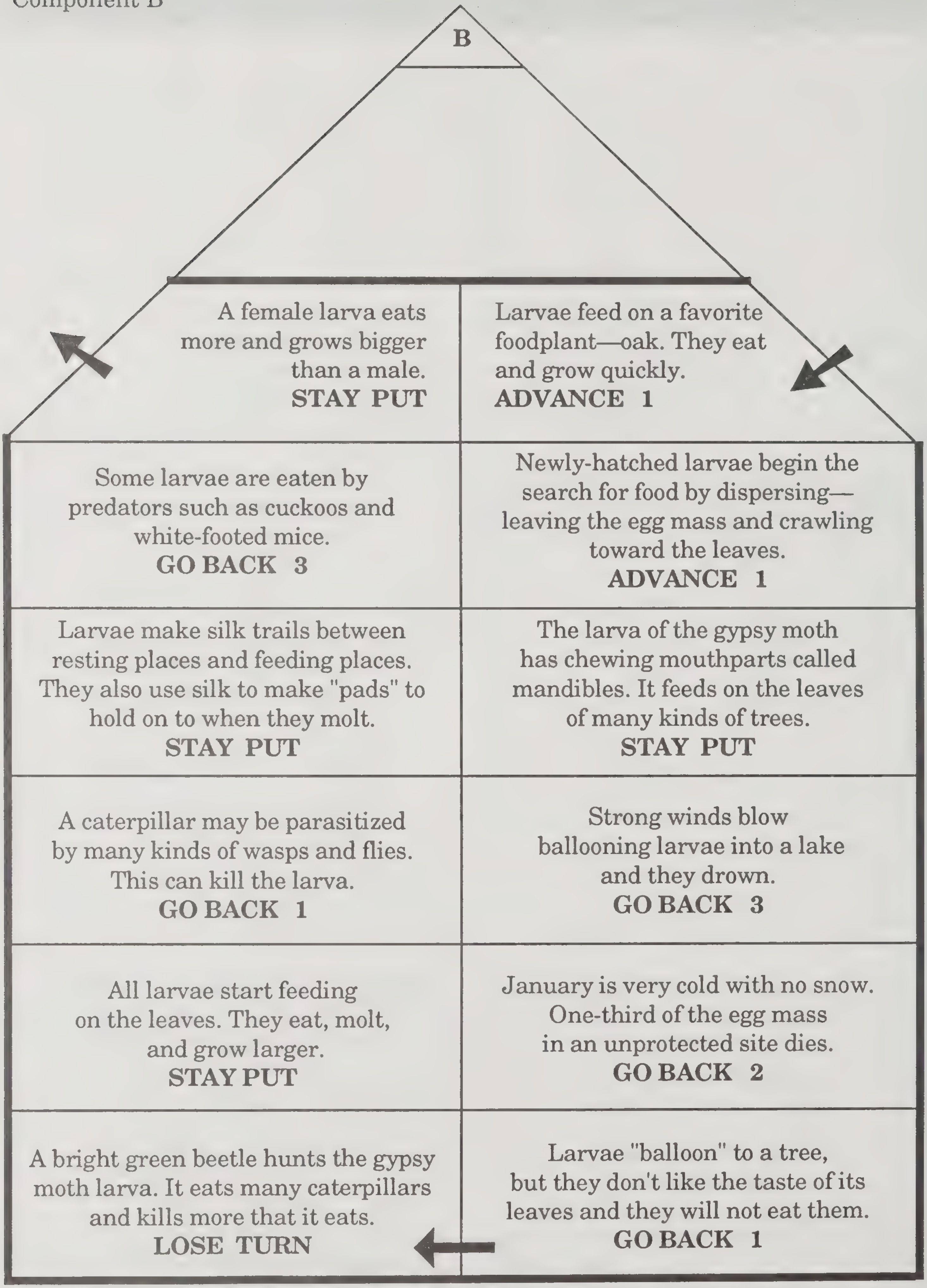
Egg mass is laid in an unprotected site on a rock.
GO BACK 1

The female adult uses hairs from her body to cover the egg mass for extra protection against the weather.
STAY PUT

Half of the eggs are attacked by tiny wasps.
LOSE TURN

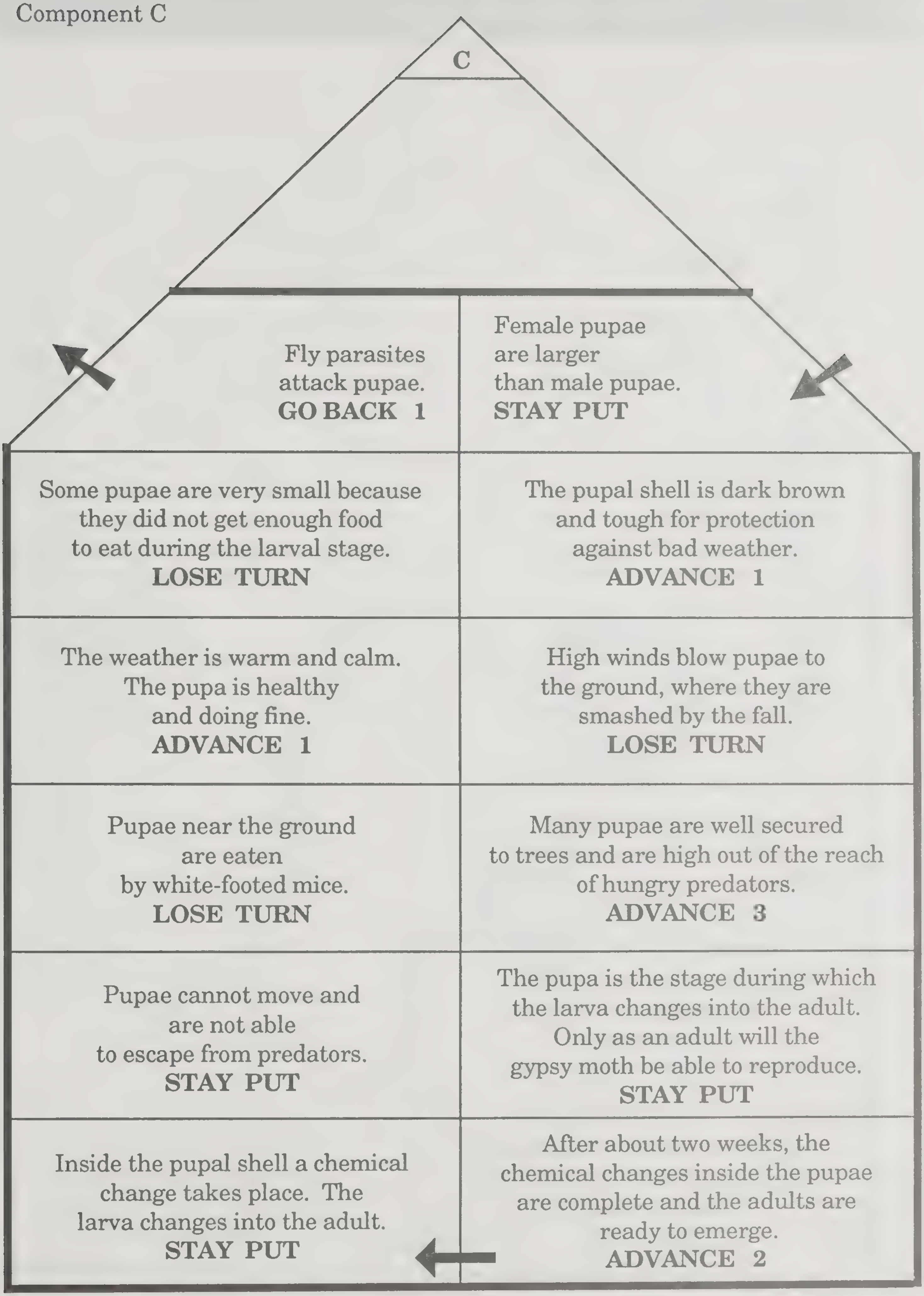
An egg mass located in a cool, shady location is slow to hatch.
GO BACK 2

Component B



A female larva eats more and grows bigger than a male. **STAY PUT**	Larvae feed on a favorite foodplant—oak. They eat and grow quickly. **ADVANCE 1**
Some larvae are eaten by predators such as cuckoos and white-footed mice. **GO BACK 3**	Newly-hatched larvae begin the search for food by dispersing—leaving the egg mass and crawling toward the leaves. **ADVANCE 1**
Larvae make silk trails between resting places and feeding places. They also use silk to make "pads" to hold on to when they molt. **STAY PUT**	The larva of the gypsy moth has chewing mouthparts called mandibles. It feeds on the leaves of many kinds of trees. **STAY PUT**
A caterpillar may be parasitized by many kinds of wasps and flies. This can kill the larva. **GO BACK 1**	Strong winds blow ballooning larvae into a lake and they drown. **GO BACK 3**
All larvae start feeding on the leaves. They eat, molt, and grow larger. **STAY PUT**	January is very cold with no snow. One-third of the egg mass in an unprotected site dies. **GO BACK 2**
A bright green beetle hunts the gypsy moth larva. It eats many caterpillars and kills more that it eats. **LOSE TURN**	Larvae "balloon" to a tree, but they don't like the taste of its leaves and they will not eat them. **GO BACK 1**

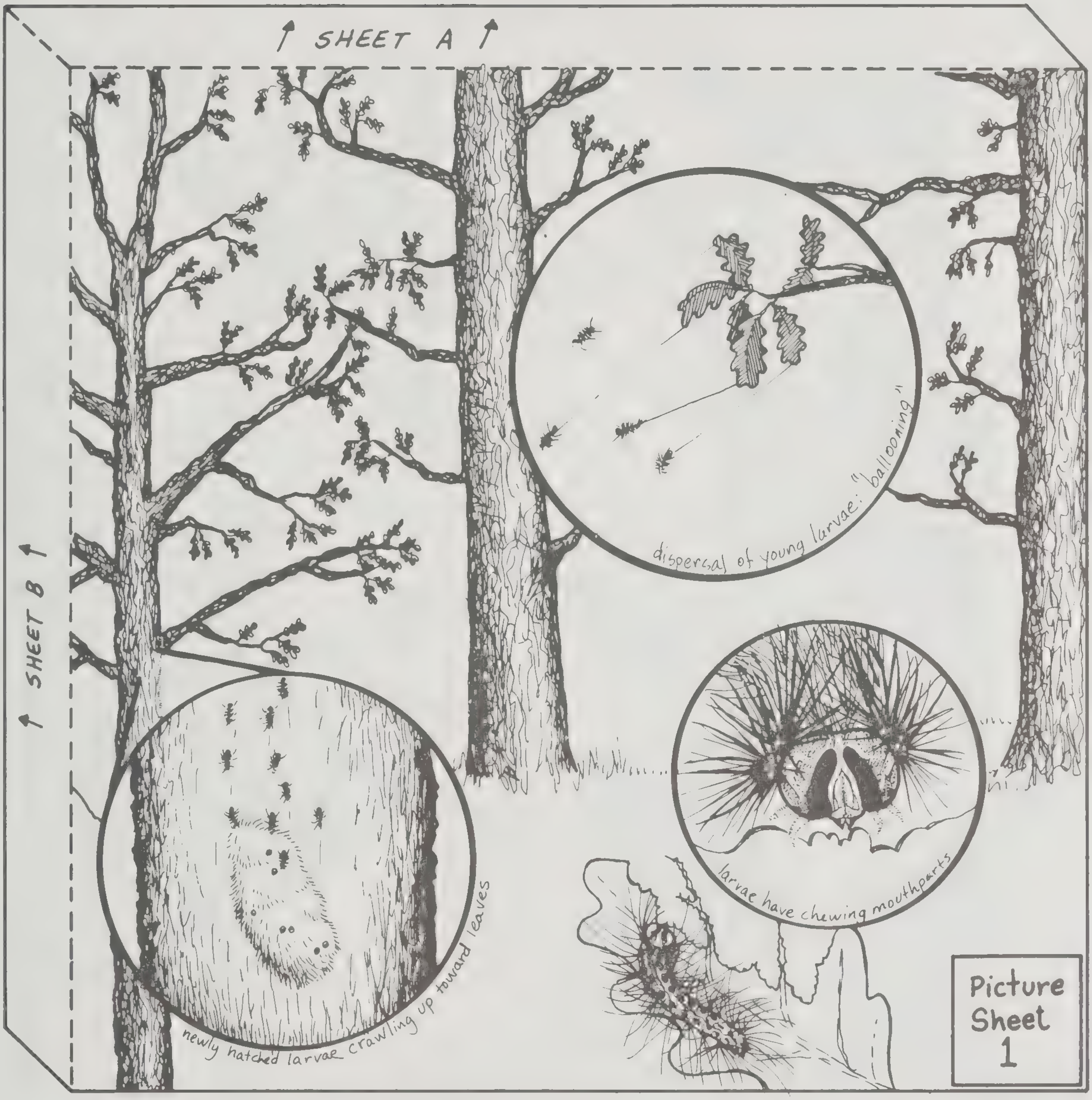
Component C

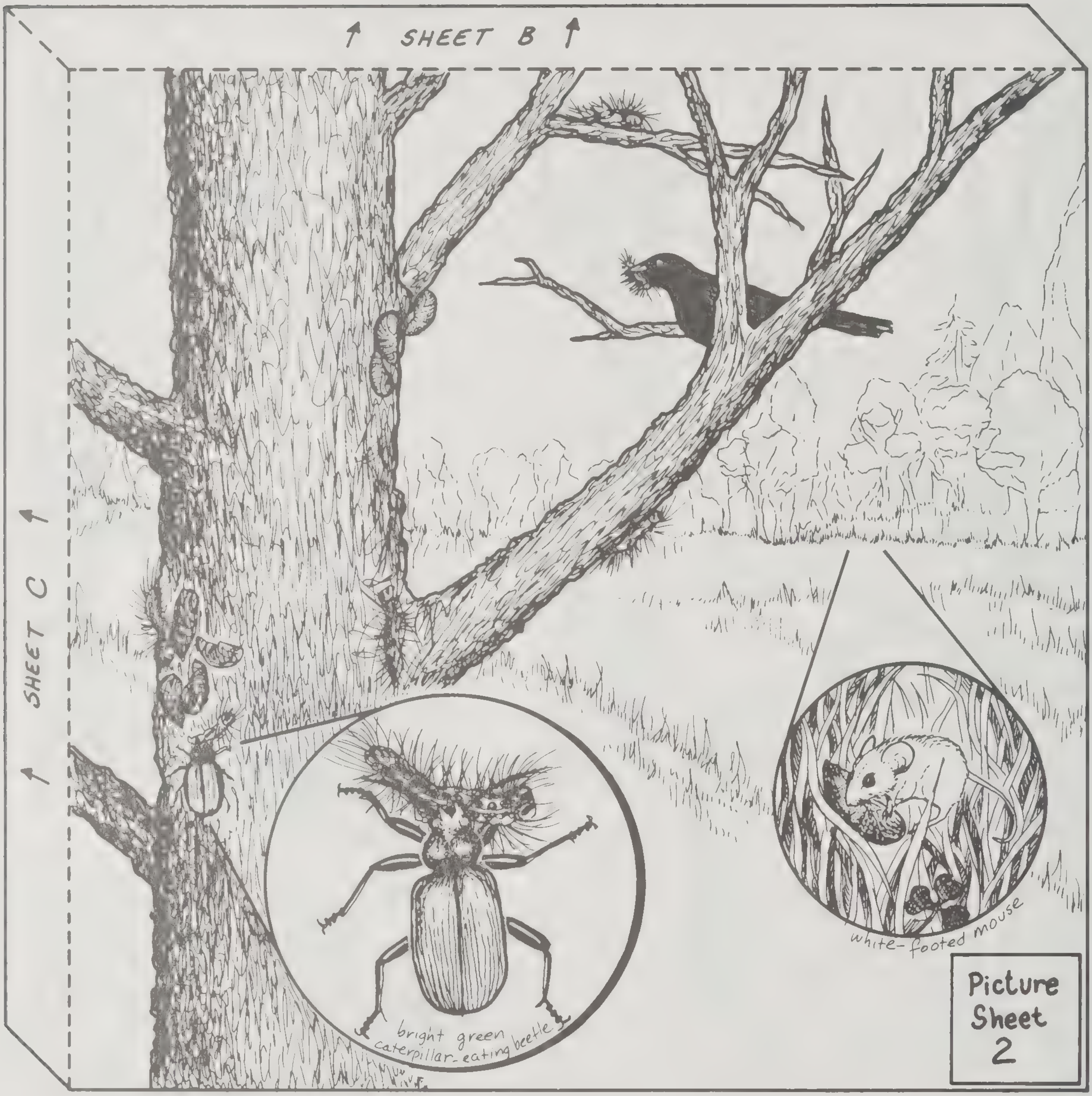


Fly parasites attack pupae. **GO BACK 1**	Female pupae are larger than male pupae. **STAY PUT**
Some pupae are very small because they did not get enough food to eat during the larval stage. **LOSE TURN**	The pupal shell is dark brown and tough for protection against bad weather. **ADVANCE 1**
The weather is warm and calm. The pupa is healthy and doing fine. **ADVANCE 1**	High winds blow pupae to the ground, where they are smashed by the fall. **LOSE TURN**
Pupae near the ground are eaten by white-footed mice. **LOSE TURN**	Many pupae are well secured to trees and are high out of the reach of hungry predators. **ADVANCE 3**
Pupae cannot move and are not able to escape from predators. **STAY PUT**	The pupa is the stage during which the larva changes into the adult. Only as an adult will the gypsy moth be able to reproduce. **STAY PUT**
Inside the pupal shell a chemical change takes place. The larva changes into the adult. **STAY PUT**	After about two weeks, the chemical changes inside the pupae are complete and the adults are ready to emerge. **ADVANCE 2**

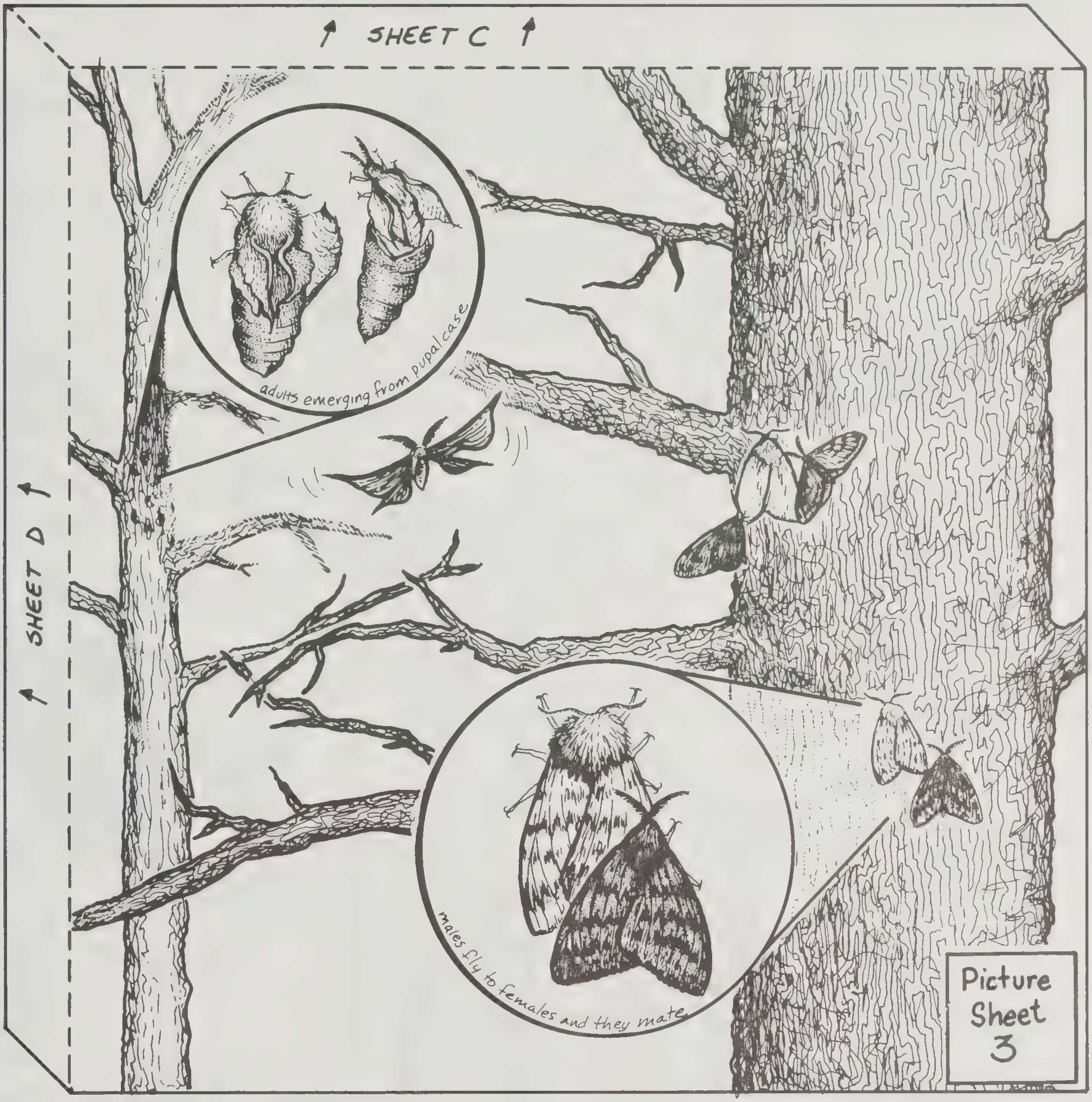
D

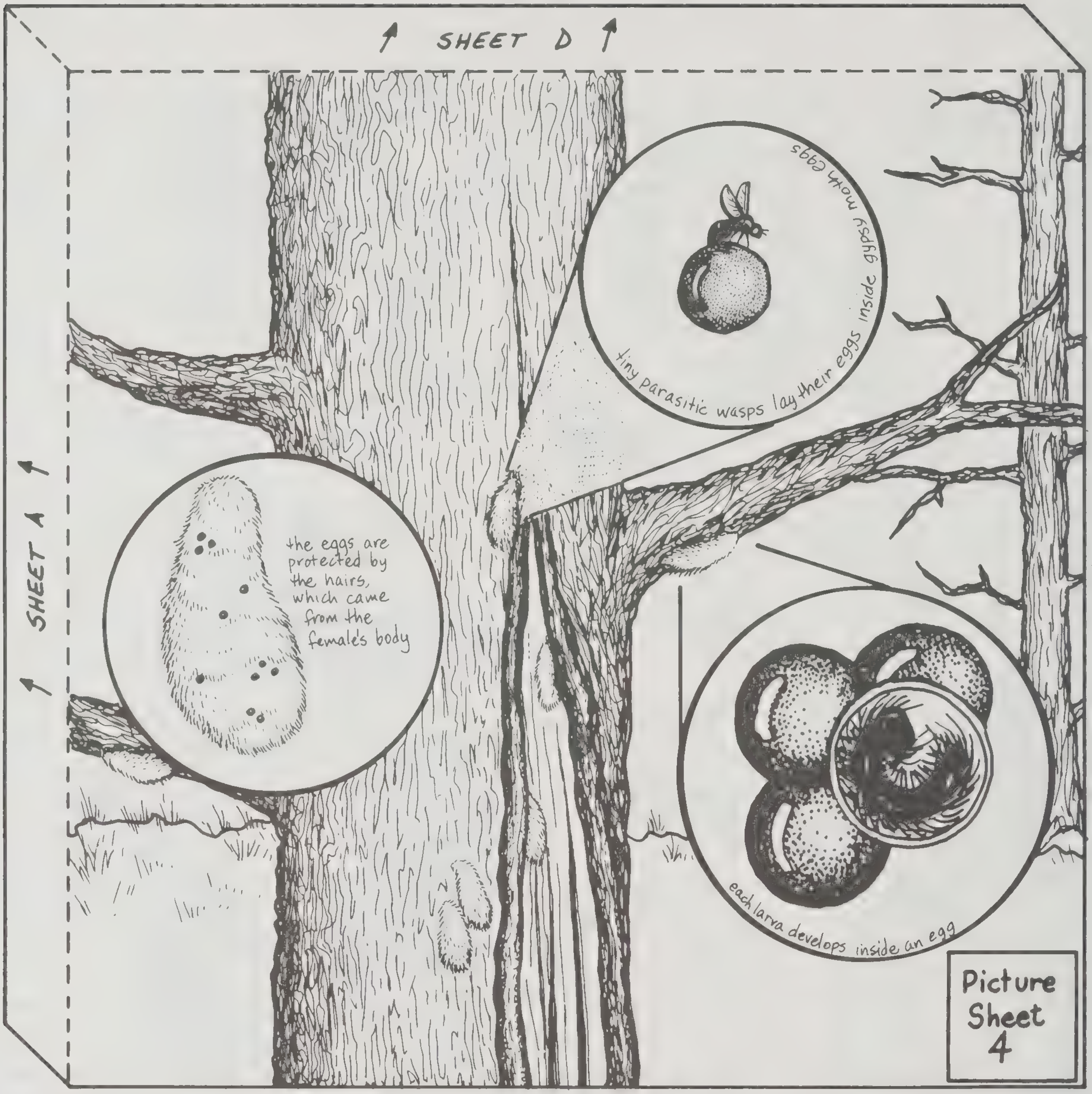
FINISH	Some of the adults are eaten by birds such as orioles and robins. **GO BACK 2**
The wind is blowing in the wrong direction and no male is attracted by the female's pheromone. **LOSE TURN**	The adult male emerges from the pupal shell and pumps blood into his brown wings until they are fully expanded and he can fly away. **ADVANCE 1**
The female gypsy moth mates and lays a large egg mass in a well-protected site on an oak tree. **ADVANCE 2**	A female gypsy moth lays an egg mass of 100 to 1,000 eggs soon after she mates. **STAY PUT**
A male gypsy moth detects the pheromone of a female with his feathery antennae and flies to her. **ADVANCE 3**	A female is knocked off the tree by a heavy downpour of rain. **GO BACK 1**
Adult gypsy moths do not eat. All the eating was done by the caterpillar. **STAY PUT**	A male gypsy moth can mate with more than one female. **ADVANCE 1**
When the male finds the female, he courts her. If she is receptive, he will mate with her. **STAY PUT**	The female produces an odor called a pheromone that only the male gypsy moth can smell. **STAY PUT**


SHEET A
SHEET B
dispersal of young larvae: "ballooning"
larvae have chewing mouthparts
newly hatched larvae crawling up toward leaves
Picture Sheet 1


↑ SHEET B ↑
↑ SHEET C ↑
bright green caterpillar-eating beetle
white-footed mouse
Picture Sheet 2

Picture Sheet 3


SHEET C
SHEET D
adults emerging from pupal case
males fly to females and they mate.
Picture Sheet 3


SHEET D
SHEET A
tiny parasitic wasps lay their eggs inside gypsy moth eggs
the eggs are protected by the hairs, which came from the female's body
each larva develops inside an egg
Picture Sheet 4

Rules of the Game

Basic Rules

1. Each player chooses a token and places it on **START**. Each token represents a gypsy moth population.

2. Each player in turn rolls the die; the player who rolls the highest number begins the game by rolling the die again and moving his or her token forward the number of spaces shown on the die. The first player then reads aloud and follows the directions printed on the square on which the token has landed. If the square on which a player lands directs the player to move to another square, the player moves to that square but does not carry out the direction printed on the second square. The die now passes to the second player, the player on the left.

3. Play proceeds in a clockwise direction. If a player's token lands on an occupied square, the player must move his or her token back 2 spaces and follow the directions on that square.

4. Play continues until each player reaches **FINISH**.

Advanced Rules

1. Each player in turn rolls the die and multiplies the number shown by 1000. This number represents the beginning size of that player's gypsy moth population.

2. The player who rolled the highest number begins the game. Play for three rounds by following the rules below. Each round of play equals one generation of gypsy moths; therefore, the number that a given student has as he or she enters each round of play represents the number of gypsy moth eggs in that generation.

3. After each roll of the die, a player does one of the following:

If the directions say:	The player:
advance 1	adds 100 gypsy moths and advances 1
advance 2	adds 200 gypsy moths and advances 2
advance 3	adds 300 gypsy moths and advances 3
go back 1	subtracts 100 gypsy moths and goes back 1
go back 2	subtracts 200 gypsy moths and goes back 2
go back 3	subtracts 300 gypsy moths and goes back 3
lose turn	loses his or her turn

4. Each keeps a running tally of his or her gypsy moth population. An example of how to keep this tally is shown on the **Tally Sheet**. If a player's population falls below 0, the population has died out. The player should continue playing the game with negative numbers in an attempt to regain a positive number.

5. The first player to reach **FINISH** receives an additional 1000 gypsy moths to add to his or her population. Before beginning Round 2, the remaining players must reach **FINISH**; they do not, however, receive the bonus of 1000 gypsy moths. The player with the largest population at the end of Round 3 is declared the winner.

6. Each player starts the new round using the gypsy moth population with which he or she ended the previous round.

Tally Sheet Name:

	Generation (round)	Starting population	Add or subtract	Total
Example:	1	400	+100	500
			-200	300

Generation (round)	Starting population	Add or subtract	Total

8.

Gypsy Moth–Forest Interactions: Background Information

Through the years scientists have studied the gypsy moth and its eating habits. Although gypsy moth caterpillars are hearty eaters and will feed on the leaves of over 500 species of trees and shrubs, they have definite food preferences. Just as most people like chocolate and ice cream more than they like liver and brussels sprouts, gypsy moths prefer the leaves of oak and birch over those of sycamore and ash. Scientists have placed the plants gypsy moth caterpillars eat into three categories of preference: preferred, intermediate, and nonpreferred plants.

Armed with information about the food prefrences of the gypsy moth and additional knowledge about other characteristics of forests that gypsy moths find attractive, scientists began to develop scientific models capable of predicting the risk of a specific area to defoliation by gypsy moths. Such predictions are important because they enable governmental agencies to make wise choices about where and how to use funds and personnel in the detection and control of the gypsy moth.

Just what impact can gypsy moths have on a forest? First, let's look at the basic ingredient of a forest—its trees. Large numbers of gypsy moth larvae are capable of eating all of the leaves of a tree (defoliation) in a very short time. When all its leaves have been stripped, a tree's food-producing factory is shut down, and the tree is forced to draw upon stored food to put out new leaves. For that growing season, the tree will add little to its size because of the stress caused by defoliation. Further, the tree will enter its dormant stage in the fall in a weakened condition. Trees that have been defoliated for two or more consecutive years often become so weak that they succumb to fungi and other diseases and eventually die. Thus, the impact of the gypsy moth on trees can be very severe over time.

What happens when you multiply the damage done to one tree by the number of trees that make up a forest? What are the effects on other members of the forest community? When most of the leaves in a forest are destroyed, birds and mammals leave because they can no longer find food and shelter. The absence of leaves also increases the erosion of soil during heavy rainfall, and humus cannot accumulate. Plants that live on the forest floor are also affected: many plants thrive only in shade, and an increase in the amount of sunlight that reaches the forest floor can have serious consequences. Ultimately, the whole forest community is affected by gypsy moth defoliation.

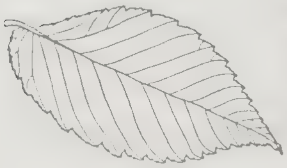
8.A Food Preference Puzzle

OBJECTIVE	to categorize trees according to the food preferences of the gypsy moth caterpillar
SKILLS/PROCESSES	visual discrimination, comparison, classification
VOCABULARY	diagonal, horizontal, intermediate, nonpreferred, preferred, vertical
MATERIALS	multiple copies of **Food Preference Puzzle** several copies of field guides to trees
COMMENTS	This activity can be used to acquaint students with the use of standard field guides to identify trees by examining their leaves. If students cannot readily identify the leaves shown on the puzzle, provide them with the names of the trees so that the activity does not bog down in problems of identification. You may choose to have a student develop an answer sheet.

PROCEDURE

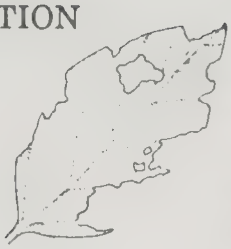
1. Demonstrate that food preferences exist by polling students about favorite foods. Gypsy moths have food preferences, too, and scientists have performed experiments to determine which leaves gypsy moth caterpillars prefer to eat. Three categories have been defined: preferred, intermediate, and nonpreferred. Every species of tree can be placed under one of these categories.

2. Distribute copies of the **Food Preference Puzzle** in which the names of 27 trees are hidden according to the preferences of the gypsy moth caterpillar. Names of preferred trees are printed horizontally, names of trees in the intermediate category are printed vertically, and names of nonpreferred trees are printed diagonally. Beneath the puzzle is a list of tree names; occasionally a picture of a leaf is given instead of a name. In those cases, students must identify the name of the tree by using a field guide. The names of the trees that are indicated only by leaves are *oak*, *maple*, *tulip tree*, *larch*, *pine*, *walnut*, and *buckeye*.



3. When students have circled the 27 tree names hidden in the puzzle, they should list them on the back of the puzzle according to the three categories of preference. If you prefer, you may develop these categories together by making a master list at the chalkboard.

EVALUATION



Bring in a collection of tree leaves that includes as many of the 27 trees in the puzzle as possible. (You can expand this collection beyond the 27 trees introduced here by referring to the preference categories given in the following activity, 8.B.) Students may help to assemble this collection, and more than one leaf of the same species will prove useful. Divide the class into groups; the size of the groups will depend on the number of field guides you have. Distribute the leaves among the groups. Students then identify the trees from which the leaves came and sort the leaves by preference categories. The leaves can also be used to create a bulletin board display that shows the preference categories, or groups may elect to make poster presentations.

Food Preference Puzzle

Name:

L	O	S	T	R	A	D	C	R	A	B	A	P	P	L	E	P
O	P	E	N	U	N	O	P	A	P	E	R	B	I	R	C	H
L	I	N	D	E	N	G	H	A	W	T	H	O	R	N	M	I
L	P	O	P	E	S	W	E	E	T	G	U	M	A	H	O	N
Y	O	W	I	L	L	O	W	C	M	O	S	T	N	A	R	D
M	A	E	N	W	O	O	N	H	A	P	P	L	E	C	N	A
A	H	N	E	A	O	D	O	E	P	L	A	E	R	K	C	T
N	E	N	E	V	P	R	A	M	L	A	R	C	H	B	H	O
T	M	O	N	D	E	N	N	R	E	T	R	Y	W	E	R	F
R	L	O	M	B	A	R	D	Y	P	O	P	L	A	R	E	O
A	O	M	O	U	N	T	A	I	N	A	S	H	L	R	D	R
S	C	E	S	C	A	L	L	M	E	A	T	T	N	Y	B	E
T	K	C	T	K	T	U	U	R	N	I	S	O	U	E	U	M
I	R	C	L	E	T	O	O	M	B	U	U	C	T	N	D	O
H	U	A	E	Y	U	M	U	N	C	H	C	H	I	G	U	T
I	G	P	L	E	A	O	E	O	A	K	S	E	N	M	T	E
N	E	L	O	C	R	R	L	B	I	A	H	R	G	A	D	H
G	O	A	Y	E	M	E	M	L	R	I	A	R	R	T	S	P
H	A	S	G	R	A	Y	B	I	R	C	H	Y	S	A	S	R

apple

paper birch

elm

cherry

_ _ _

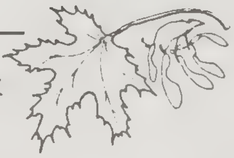
holly

sweetgum

dogwood

ash

_ _ _ _ _ _



hemlock

locust

_ _ _ _ _ _   _ _ _ _ _ _

sycamore

mountain ash

hawthorn

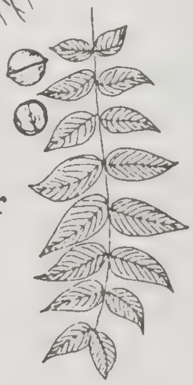
_ _ _ _ _ _

crabapple

_ _ _ _ _

gray birch

_ _ _ _ _ _ _



hackberry

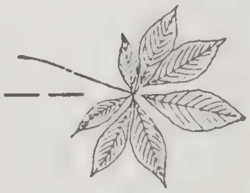
lombardy poplar

linden

redbud

willow

_ _ _ _ _ _ _ _



8.B Developing a Scientific Model

OBJECTIVE

to acquire the skills needed to develop a simple scientific model capable of predicting the susceptibility of trees to defoliation by gypsy moth caterpillars

SKILLS/PROCESSES

observation, organization, classification, synthesizing

VOCABULARY

data base, defoliation, plant stress, rating (noun), resistant, scientific model, susceptibility

MATERIALS

5 paper or plastic bags for each student
multiple copies of **Field Data**, **Preference Categories**, and **Susceptibility Model**
tape measure, meterstick, or string marked off in 1-m lengths
field guides to trees

PROCEDURE

1. This activity may be initiated on a field trip or as a homework assignment. Before students begin collecting data, explain that a tree's general physical condition can be ascertained by looking at such characteristics as number of large broken branches, wounds or scars on the tree trunk, and premature yellowing or browning of leaves. Each student is responsible for collecting leaves from at least five species of trees.

2. After a student selects a leaf, he or she places it in a paper or plastic bag, assigns it a number, and records that number on the bag and on a copy of the **Field Data** sheet. If time permits, the tree should be identified at the site by referring to a field guide. The preference category may be assigned later back in the classroom.

3. Before leaving the site, the student completes the descriptions of physical condition and location for each tree.

4. Complete the data sheets back in the classroom. Students may need help identifying trees; they will also need copies of **Preference Categories**. You may wish to review the preference categories introduced in the previous activity, 8.A.

5. Discuss the concept of **susceptibility**. Explain that a preferred tree is more susceptible, that is, more likely to have some or all of its leaves eaten by gypsy moth caterpillars. Emphasize, however, that such factors as broken branches, wounds, root damage, and inadequate water also affect the health of a given tree and contribute to its susceptibility to defoliation by gypsy moth caterpillars. In short, trees under **stress** are more susceptible to defoliation than healthy trees and preferred tree species are more susceptible to defoliation than intermediate or nonpreferred species.

6. Introduce the concept of a **scientific model**. Explain that a model is an equation or series of equations with one or more variables. The scientific model uses information gathered from direct observation (data) to help understand how nature works or to predict future events. In our tree susceptibility model below, the data we collected about the condition and location of a given tree and its preference category are used in an equation to predict the susceptibility of that tree to defoliation by gypsy moth caterpillars.

7. Distribute copies of the **Susceptibility Model**. Using the information on these sheets and on the **Field Data** and **Preference Categories** sheets, each student rates each of the five trees that make up his or her data base by following these directions:
   a. Rate each tree based on the preference of the gypsy moth caterpillar for that species of tree. The data from any tree not listed on the preference sheet should be discarded. For example: oak = preferred = -1; ash = nonpreferred = +1. This value will be used to replace A when computing the Susceptibility Index for a given tree.
   b. Rate each tree based on its physical condition. For example: healthy tree = +1; unhealthy tree = -1. This value will be used to replace B when computing the Susceptibility Index for a given tree.
   c. Rate each tree based on its location. For example: < 2 meters from a building = -1; in an open area = +1. This value will be used to replace C when computing the Susceptibility Index for a given tree.

8. Students are now ready to compute the Susceptibility Index for each of the trees in their data bases. The higher the value, the more resistant the tree. For example:

   A = -1 (species = oak = preferred)
   B = -1 (condition = unhealthy)
   C = -1 (location < 2 meters from a building)

$$\begin{aligned} \text{Susceptibility Index} &= 3A + 2B + 1C \\ SI &= 3(-1) + 2(-1) + 1(-1) \\ SI &= -3 + -2 + -1 \\ SI &= -6 \end{aligned}$$

   By referring to the Susceptibility Scale, we conclude that this particular oak is highly susceptible to defoliation by gypsy moth caterpillars.

9. If your students are working with computers, they may create a program that will accommodate the model. Students can then use the program with the data they have collected. Advanced students may also be interested in the following publication from the Illinois Natural History Survey:

Swofford, D.L. , M.R. Jeffords, and K.W. O'Hayer. 1988. Predicting the Susceptibility of Illinois Forest Stands to Defoliation by the Gypsy Moth. Illinois Natural History Survey Biological Notes 131. 4pp.

10. After each student has calculated the susceptibility of five trees, he or she should calculate the average susceptibility of this "forest" of five trees.

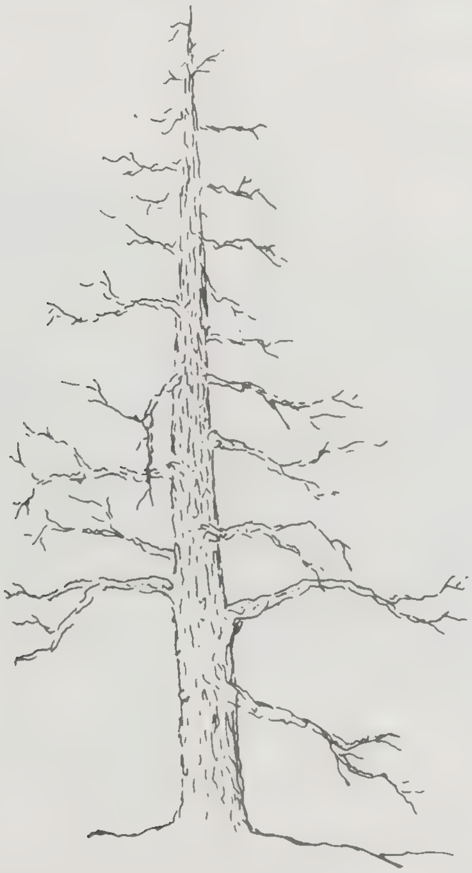
11. Compile the susceptibility indices of all trees rated by the class. Then determine the percentage of trees in each of the five susceptibility categories. Students then present this information in graphic form. Encourage a variety of approaches: bar graph, column graph, line graph, scatter graph, or pie graph.

12. Students will enjoy pressing the leaves they collected in a plant press or under a pile of heavy books. They can then prepare herbarium specimens following the directions provided in the reference below.

    Robertson, K.R. 1980. Observing, Photographing, and Collecting Plants. Illinois Natural History Circular 55. 62pp.

EVALUATION

Give each student a set of ten or more specimens to represent a local forest. The student determines the susceptibility of this forest to defoliation by gypsy moth caterpillars by applying the model to each tree and averaging the susceptibility indices for all trees.



Field Data Name:

	Tree no. ___ Species ___	Tree no. ___ Species ___	Tree no. ___ Species ___	Tree no. ___ Species ___	Tree no. ___ Species ___	Tree no. ___ Species ___
A. Preference category of tree						
nonpreferred species	☐	☐	☐	☐	☐	☐
intermediate species	☐	☐	☐	☐	☐	☐
preferred species	☐	☐	☐	☐	☐	☐
B. Physical condition of tree						
very healthy (green leaves, no wounds, no yellow or brown leaves, no broken or dead branches)	☐	☐	☐	☐	☐	☐
moderately healthy (mostly green leaves, a few yellow or brown leaves, no wounds, few broken or dead branches)	☐	☐	☐	☐	☐	☐
unhealthy (yellowish or brown leaves, one or more wounds, many broken or dead branches)	☐	☐	☐	☐	☐	☐
C. Location of tree						
open area with building or pavement >8 meters away	☐	☐	☐	☐	☐	☐
2–8 meters from a building, sidewalk, driveway, street, etc.	☐	☐	☐	☐	☐	☐
<2 meters from a building, sidewalk, driveway, street, etc.	☐	☐	☐	☐	☐	☐

Preference Categories

Preferred	Intermediate	Nonpreferred
oaks	maples	sycamore
birches	elms	ashes
apples	pines	tulip-tree (yellow poplar)
crab apples	hemlock	black locust
willows	cherry	honey locust
sweet gum	hackberry	holly
hawthorn	redbud	white cedar
mountain ash	dogwood	arborvitae
larch	walnut	azalea
poplar (Lombardy)	buckeye	balsam fir
linden (basswood)	beech	bald cypress
alder	plum	catalpa
aspens	bayberry	American box elder
blueberry	butternut	viburnum
hazelnut	hickory	honeysuckle
spruces	pear	horse chestnut
sumacs	sassafras	osage orange
witch hazel	persimmon	
cedars		

Susceptibility Model Name:

Model for determining susceptibility of a tree to defoliation by gypsy moth caterpillars

Factors	Rating
Preference category of tree = A	
nonpreferred	+1
intermediate	0
preferred	-1
Physical condition of tree = B	
very healthy	+1
moderately healthy	0
unhealthy	-1
Location of tree = C	
open area	+1
2–8m from building or pavement	0
<2m from building or pavement	-1

Susceptibility Index = 3A + 2B + 1C

The factors of 3, 2, and 1 are weights that indicate the relative importance of A, B, and C.

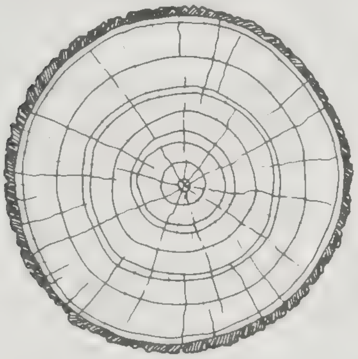
Susceptibility Scale

-6 -5	-4 -3	-2 -1 0 1 2	3 4	5 6
highly susceptible	moderately susceptible	intermediate	moderately resistant	highly resistant

8.C Effects of Defoliation

OBJECTIVE	to understand how defoliation by gypsy moths and other forms of stress affect trees
SKILLS/PROCESSES	analysis, comparison
VOCABULARY	annual ring, cross section, diameter, plant stress, succumb
MATERIALS	Multiple copies of **Cross Section of a Tree** or access to an overhead projector

PROCEDURE



1. Distribute copies of **Cross Section of a Tree** or make a transparency for the overhead projector. Referring to this illustration, explain that as a tree grows, its trunk grows larger in diameter. The diameter gets larger each year because the tree adds an annual ring of new growth just outside the one from the previous year (but still inside the bark layer). The width of an annual ring indicates how much the tree grew that year. If the tree grew a lot, the annual ring will be wide; if the tree grew only a little, the annual ring will be thin. Number the rings on the cross section to determine the age of the tree. (The very small inner circle is year one). In which years did the growth of the tree seem restricted or below average?

2. Discuss the conditions necessary for the growth of a tree. Its leaves convert water, carbon dioxide, and light energy into plant growth. Carbon dioxide is present in sufficient amounts even in very polluted air, but if *water*, *light energy*, or *leaves* are not present in sufficient quantities, the tree cannot make enough food to grow. The tree may, in fact, become weak and sick. Such a tree is said to be undergoing **stress**. When a tree is stressed, it may succumb to disease and die. At what ages did the tree shown in the cross section experience stress?

3. Present the following scenarios to your class and decide in each instance which ingredients essential for good tree growth were missing. Emphasize that in each case the tree will undergo stress.
   a. There is little rain from April through September.
   b. Street repairs are taking place, and a tar truck parks under a tree. Heat from the truck burns the tree's leaves and they fall off.
   c. Neighboring trees are very tall and they shade the small tree.
   d. Gypsy moth caterpillars eat all the leaves of a tree.

e. Construction workers put up a tall building near a tree. Now the tree is in the shade of the building all day long. Cement is poured around the base of the tree to make a sidewalk and a parking lot.

f. A deer eats all the leaves off a small tree.

4. Below is the chronology of an oak tree from the year it sprouted from an acorn until the year it died. Read this description as students draw a cross section that represents what happened. Ask them to number each annual ring and to list the years during which the tree was stressed. If you prefer, the cross section may be drawn at the chalkboard or on the overhead projector.

Year 1: Neighboring trees are very tall. Not much sunlight reaches the young oak sapling.

Year 2: The young sapling remains short; the neighboring trees continue to shade it heavily.

Year 3: The neighboring trees are cut down for firewood. Plenty of sunlight now reaches the young oak. Abundant rain falls.

Year 4: There is plenty of rain and sunlight.

Year 5: There is plenty of rain and sunlight.

Year 6: There is plenty of rain and sunlight.

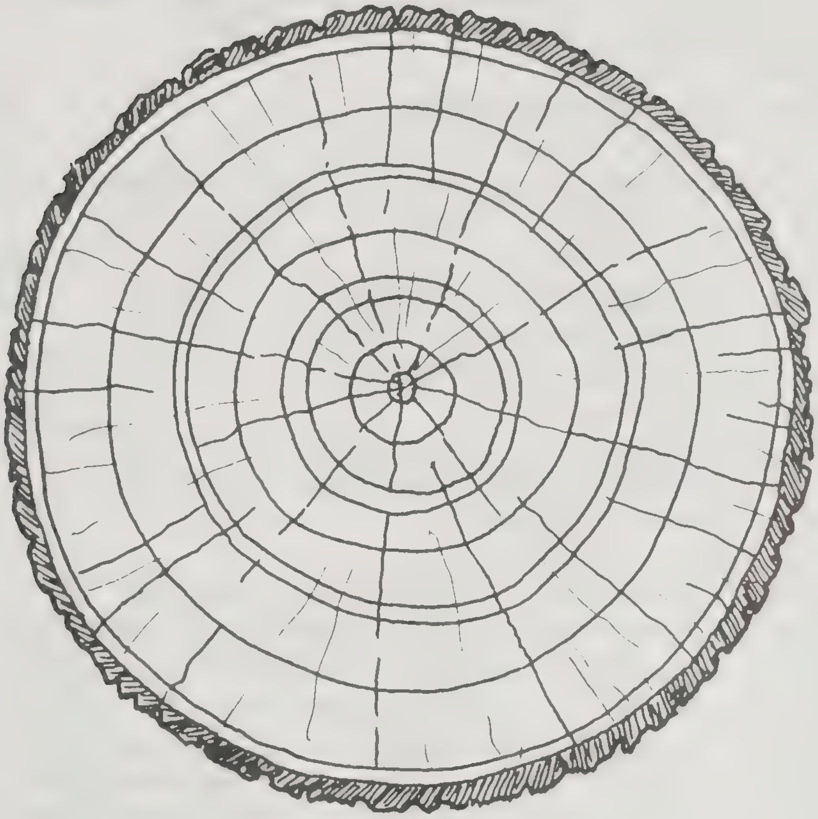
Year 7: Gypsy moth caterpillars eat the tree's leaves. Almost all of its leaves are eaten; however, the tree grows new leaves in late July after the caterpillars have become pupae. The tree barely manages to make enough food to survive the winter.

Year 8: The tree has barely survived the winter. Numbers of gypsy moth caterpillars are again large in the spring, and the tree is again defoliated. The tree is invaded by a fungus infection; in its weakened condition, it dies.

EVALUATION

Locate several cross sections of trees. Students who live in homes with fireplaces will be able to help. Recreate the chronology of the trees from which these cross sections were taken. Which rings represent normal growth? Which rings reflect years of stress? Each student then writes the life history of one of the trees shown in cross section. Students may elect to complete this exercise in a number of ways. Some may, for example, write an objective report that provides reasonable explanations for the lean years. Others may choose to write the story from the point of view of the tree, from the point of view of a homeowner who has used the tree for landscape purposes, or even from the point of view of an occupant of the tree. Drawings of the cross section should accompany these reports.

Cross Section of a Tree



8.D Population Dynamics

OBJECTIVE to demonstrate through simulation how and why populations of organisms change over time

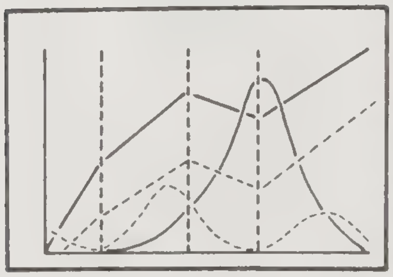
SKILLS/PROCESSES analysis, data interpretation, inference

VOCABULARY density dependent, density independent, habitat, predator, prey, simulation

MATERIALS

32" × 32" board or cardboard, one for each game
8 1/2" × 11" pieces of lightweight cardboard
30 red, 30 blue, and 12 white poker chips per game board
glue, pushpins, black marker
opaque or overhead projector
multiple copies of **Data Sheet: Population Game** and
Density-independent Cards

COMMENTS



The interactions that occur among animals living in the same community are varied and complex. All animals are either predators or prey, and most animals are both. The effect that predators and prey have on each other's population numbers is an important area of ecological research. Scientists want to learn why and how cycles in predator and prey numbers occur. Two basic concepts are involved in interactions between predators and prey: a) predators reduce the numbers of their prey, and b) prey populations largely determine the growth rate of predator populations because prey provide the food necessary for predator growth and reproduction.

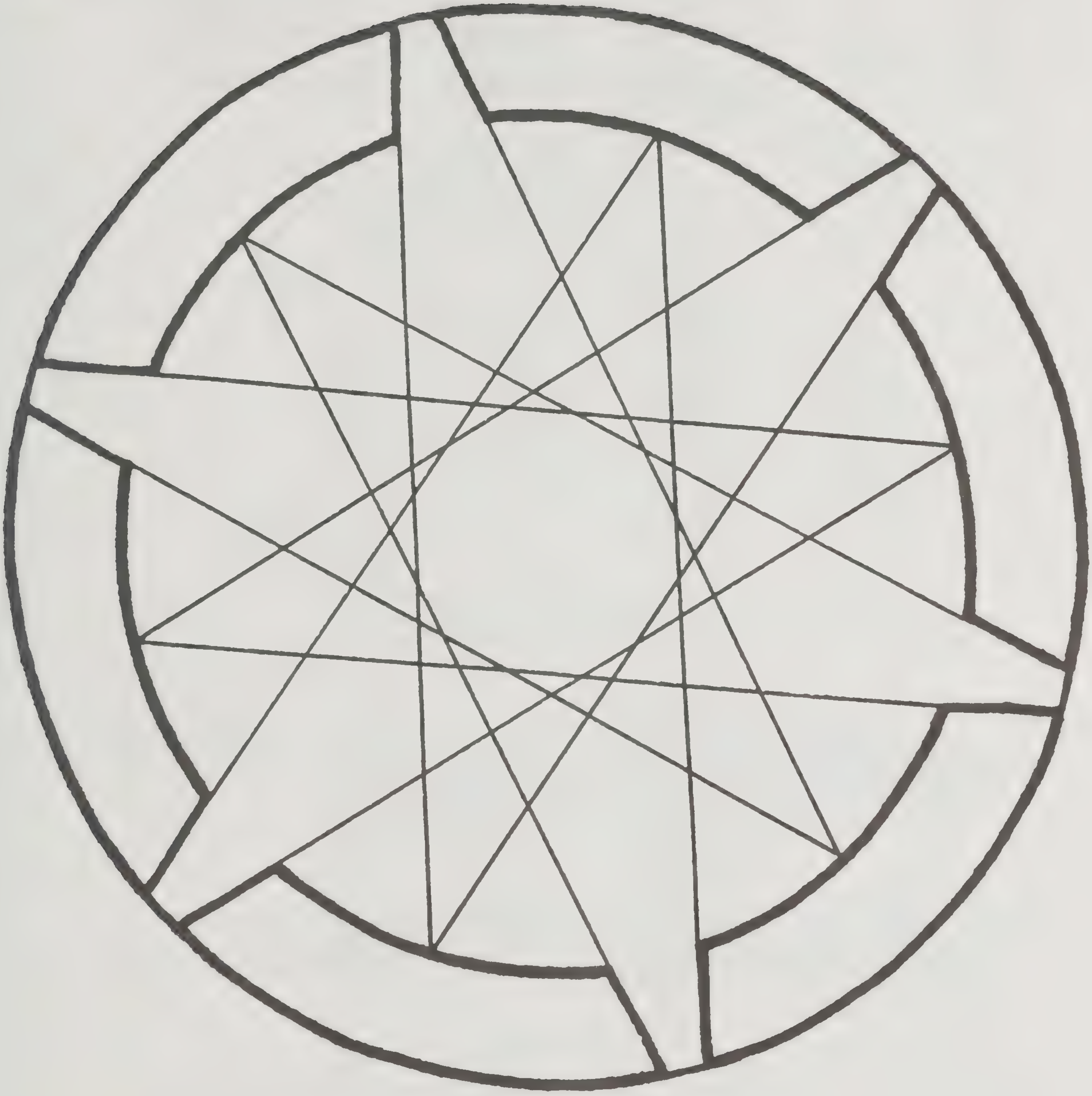
The population game described in this activity represents a simplified version of predator/prey interactions. The game board represents a forest habitat. The prey are gypsy moths and the predators are predaceous beetles, small mammals, or parasitic wasps.

Prey populations vary with the ability of predators to capture prey. When predators capture large numbers of prey, the population decreases and the predators become less successful at capturing prey. This reduces the predators' reproductive rate, and prey numbers now have a chance to increase again. As prey numbers increase, predators again capture larger numbers of prey. This cycle tends to repeat itself through time. This population game allows students to simulate the effects that predators and prey have on each other's numbers.

GAME CONSTRUCTION

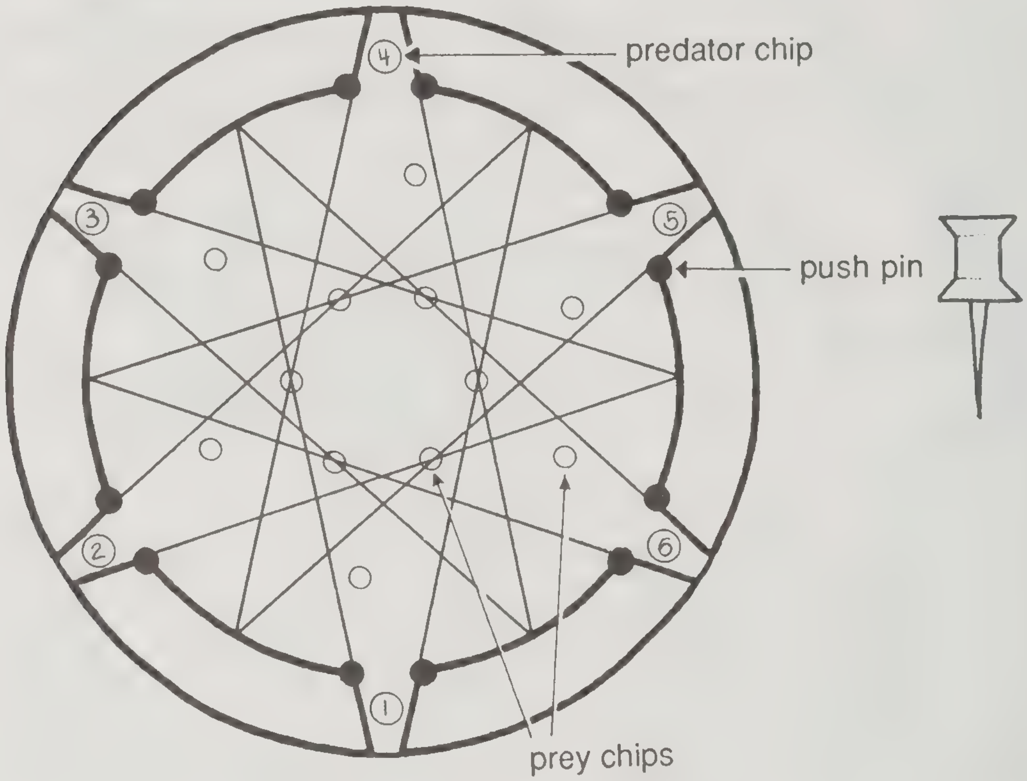
1. Construct one or more game boards in advance or assign the construction tasks to small groups of students. Begin by tacking or taping the 32" × 32" board or cardboard to the wall. Using an opaque projector, project the game board design (following page)

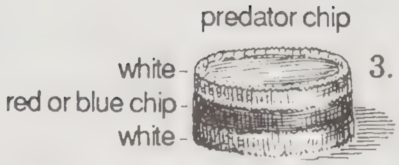
GAME BOARD DESIGN



onto the board. Move the projector until the gameboard circle has an outside diameter of 30 inches. Then trace the projected game board. (If you use an overhead projector for this task, you will need to begin by making a transparency of the design.)

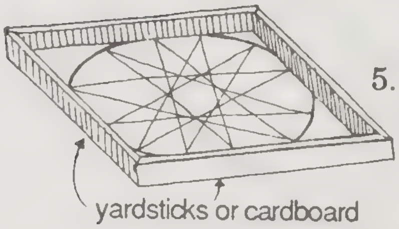
2. Lay the gameboard flat and place 12 pushpins at the locations shown below.





3. Prepare three male and three female predators by gluing a red poker chip between two white chips for each female and a blue chip between two white chips for each male.

4. Construct a bumper around the game board with yardsticks, metersticks, or cardboard.



5. Rather than providing a copy of the rules and having your students read them, explain and demonstrate the procedures and follow the game instructions described on the following pages.

Basic Game

1. Assign six students to each board. Explain that the game mirrors what happens in the world of prey and predator interactions. The game board represents a forest habitat that is occupied by gypsy moths (prey) and predaceous beetles, small mammals, and parasitic wasps (predators). Following the positions shown in the illustration above, place 6 red chips on the board to represent 6 female gypsy moths and 6 blue chips to represent 6 males. Then position the 6 predators: 3 females (red "sandwich chips") and 3 males (blue "sandwich chips").

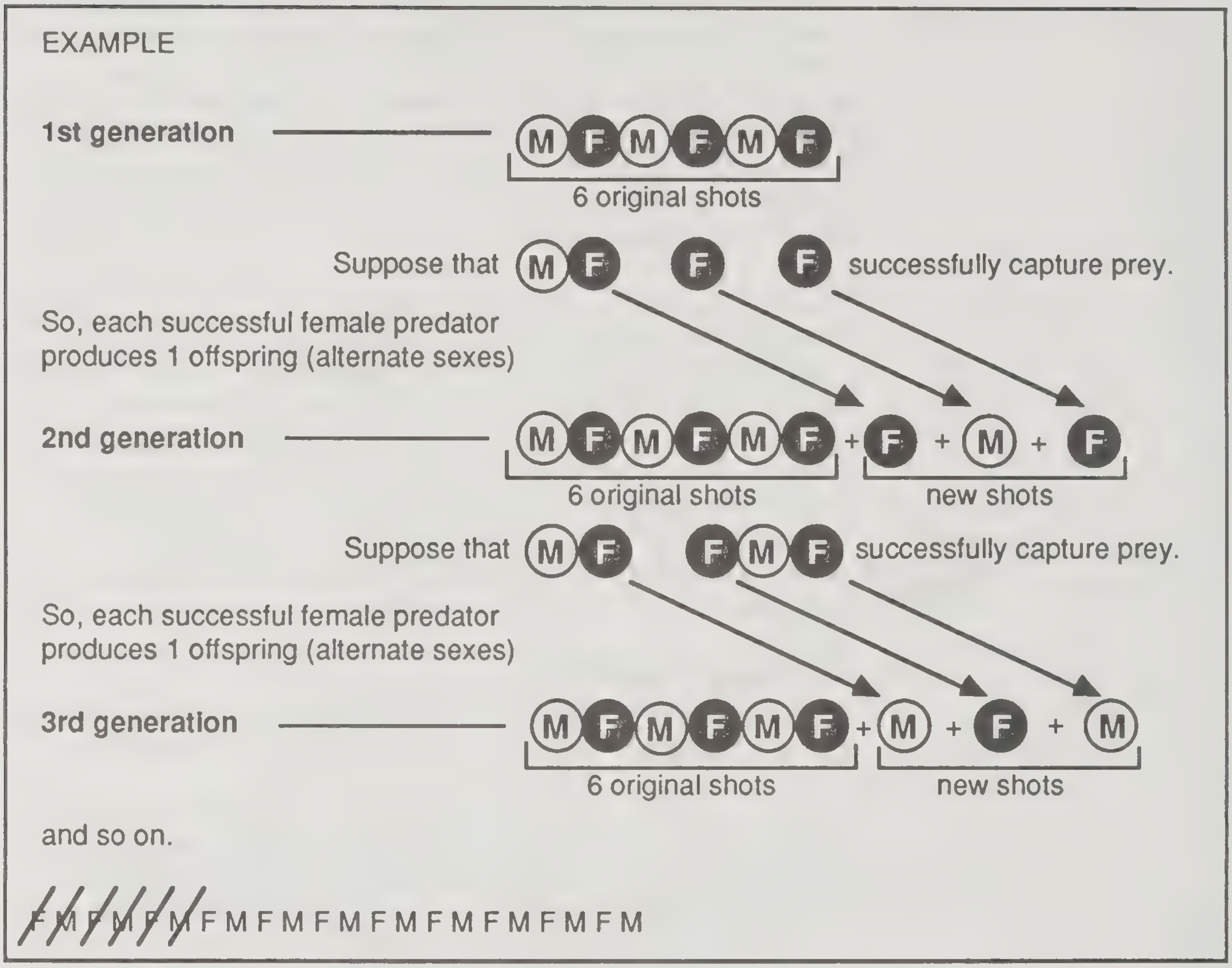
2. Prey are attacked by predators by flicking one of the 6 sandwich chips with the forefinger placed against the thumb. Only one predator may be flicked at a time, and only prey within the area delineated by the pushpins may be attacked. A predator is successful in capturing a meal when it knocks at least one prey chip out of the inner circle. If a prey chip is hit and moved but stays within the inner circle, it remains in play. If a prey chip touches the boundary of the inner circle, it is counted as a successful capture. Successfully captured prey are removed from the board.

3. Each round of shots represents one generation of prey and predator. The first round has only 6 shots, one by each of the six players. The number of shots in subsequent rounds will vary.

4. Distribute a copy of **Data Sheet: Population Game** to each group of players. At the end of each round of play (each generation), students count all prey chips that are "alive" and record this information in column B. The number of living female prey (red chips) is recorded in column C. The number of female predators (white and red sandwiches) that were successful in capturing prey is recorded in column D.

5. Both prey and predators "reproduce" before the next round of play. *Prey* reproduction (column E) is based on the number of female prey that survived the previous round. For each surviving female prey, place two more offspring (one blue and one red chip) on the board.

   Predator reproduction (column F) is based on the success of female predators. For each female predator that successfully captured at least one prey, add one predator offspring to the board at the same location as its "mother." Alternate the sex of these offspring—blue sandwich, red sandwich—following the pattern shown on the bottom of the **Data Sheet**. Predator offspring remain on the board for one generation only. In other words, during the next round of play, in addition to the regular 6 shots, one extra shot will be taken from the location of each female predator that was successful in the previous round. All female predators that were successful in capturing prey reproduce, and only the newest offspring are added to the original 6 predator shots for the next round.



EXAMPLE

1st generation — M F M F M F — 6 original shots

Suppose that M F F F successfully capture prey.

So, each successful female predator produces 1 offspring (alternate sexes)

2nd generation — M F M F M F + F + M + F — 6 original shots, new shots

Suppose that M F F M F successfully capture prey.

So, each successful female predator produces 1 offspring (alternate sexes)

3rd generation — M F M F M F + M + F + M — 6 original shots, new shots

and so on.

~~F M F M F M~~ F M F M F M F M F M F M F M F M

6. The population game may be played for as many generations (rounds) as desired, but at least six generations are needed to obtain adequate data for graphing and discussion. As play continues, be sure that students complete all columns on the **Data Sheet.**

7. After at least 6 generations, students graph the results on axes like those shown on the following page. A solid line is used to represent prey numbers and a dashed line to represent predator numbers. The completed graph reflects changes in prey and predator populations over time.

8. After the graphs are drawn, discuss what occurred during the game. Emphasize two basic ecological concepts: a) numbers of organisms change with time; and b) numbers of prey affect numbers of predators and vice versa.

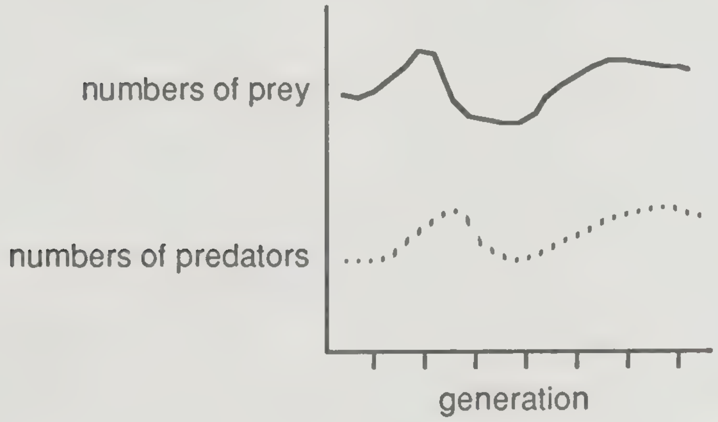
Expanded Game

The predators used in the population game are density dependent; that is, as prey numbers change, predator numbers also change. After students have played the game as described above, they may enjoy playing the expanded version described below.

1. The impact of prey/predator interactions is again recorded on the **Data Sheet** and the results are graphed as described earlier. The new dimension is the use of **Density-independent Cards**. You will need as many copies of these cards as you have game boards. Paste each sheet on an 8 1/2" × 11" piece of lightweight cardboard and cut apart the cards. These cards reflect density-independent factors that act on a group of organisms regardless of their numbers: drought, flood, fire, tornadoes, insecticides, and the like.

2. Shuffle the pack of density-independent cards and place them face down beside the playing board. At the beginning of each new round (generation), select the top card from the stack and follow the instructions printed on it. This version of the game helps students to understand that many factors in addition to prey/predator interactions influence the numbers of organisms found in a community.

3. At the end of the game, discuss questions like these: What happened when density-independent factors affected only prey? only predators? What happened when both prey and predators were affected? Compare the graph made from this data (Expanded Game) with the data from the Basic Game. Did the density-independent factors change the results? If so, how?



Data Sheet: Population Game

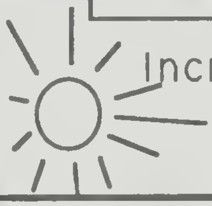
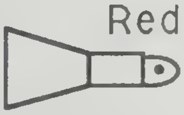
Name:

A Generation (round)	B Number of prey alive at end of round (red and blue chips)	C Number of female prey alive at end of round (red chips)	D Number of female predators that caught prey (red and white sandwiches)	E Number of prey offspring in next generation (2 x column C)	F Number of predator offspring in next generation (1 x column D)*	G Number of prey in next generation (columns B + E)	H Number of predator shots in next generation (6 + column F)

*Keep track of the sex of predator offspring by crossing out an M (male) or F (female) as each is used.

M F M F M F M F M F M F M F M F M F M F M F M F M F M F M F M F M F M F M F

Density-independent Cards

COLD SPRING Reduce prey population by 20 % (Predators not yet active - no effect)	**SUMMER DROUGHT** Increase prey population by 25% (No effect on predators)
■ INSECTICIDE SPRAYED ■ **Reduce prey by 50%** **Reduce predators by 8 shots**	 HEAVY RAIN **Reduce prey by 50%** **No effect on predators**
gypsy moth **DISEASE EPIDEMIC!** *Predators get* **3** *extra shots at slow prey* 	SEVERE WINTER Reduce prey population by *40 %* Reduce predator shots by 1
⊘ ABUNDANT FOLIAGE ⊘ Increase prey population by 10%	PERFECT SPRING WEATHER  Increase prey population by 20%
HOMEOWNERS SCRAPE EGG MASSES OFF BUILDINGS  Reduce prey population by 2%	PREDATORS EMERGE TOO EARLY **No predator reproduction this year**
USDA RELEASES PARASITES **Predators get 4 extra shots**	TREES HAVE DISEASE, FEWER LEAVES PRODUCED Reduce prey population by 25%

9. The Urban Forest: Background Information

The majority of Americans live in urban or suburban settings. While most people no longer open their doors into an undisturbed forest, they may have the opportunity to live on a small piece of land of their own. They often enjoy choosing plants and trees for their yards and managing them to suit themselves. Most homeowners establish a mixture of trees, shrubs, and flowering plants. The combination of all these yards along with parks maintained by municipalities make up the urban forest.

We control the composition and density of native plant species in the urban forest and often add ornamental species from other countries (Japanese maple, for example). In the natural forest, however, we have less effect on the composition of species. The species that make up the natural forest are largely determined by how organisms are adapted to the environment and to each other.

The diversity of plant and animal species in the urban forest differs greatly from that in the natural forest. Species diversity is a measure of the variety of species in a community. A more diverse community has more species than a less diverse community, even when individuals of each species are present in low numbers. A less diverse community has fewer species, even when individual organisms are present in large numbers. With this definition in mind, we can generally say that the urban forest is less diverse than the natural forest.

To illustrate, compare a "typical" half-acre yard with an area of equal size in the natural forest. The ground cover of the yard is usually composed of one species of grass bounded by paved sidewalks and a driveway; perhaps a flower or vegetable garden is also present. Existence of animals below the ground is discouraged by homeowners, who use chemical pesticides and rototillers. Here, dead wood and leaves are not tolerated. However, the ground cover of the natural forest consists of several types of grasses and a variety of wildflowers, ferns, and shrubs, and many animals that live below the ground surface. Dead trees and fallen leaves provide habitat and food for a variety of fungi, plants, and animals. In the urban forest, bushes and shrubs—which are often ornamental species—are usually planted in groupings of the same species for aesthetic reasons. Most yards display only a handful of plant species, and not many animals live in such a sparse environment. On the other hand, the natural forest contains a wide variety of bushes and shrubs, as well as many animals that live in them. The species of trees in the urban forest may differ from those in the natural forest because of the planting of ornamental trees. Many times, special fertilizers or pesticide applications are necessary to ensure survival of ornamental trees and shrubs. The trees of the natural forest are almost always native to the region and are well adapted to local environmental conditions.

From the forest floor to the top of the tree canopy, plants in the natural forest offer many different levels in which animals can live. These various levels of plant life create many habitats and provide foods that allow a great variety of animals to survive there. In the urban forest, however, the reduced number of plant species and levels of growth in combination with sidewalks, driveways, streets, and parking lots provides less habitat and food for animals. As a result, not as many species of animals can live in the urban forest. The *types* of animals that can live in an urban forest also differ from those that live in a natural forest.

In summary, the urban forest has a much simpler physical appearance, trophic structure, and diversity than the natural forest and provides less habitat and fewer food resources for wild animals.

9.A The Urban versus the Natural Forest

OBJECTIVE

to discover differences in diversity, complexity, and disturbance between the urban and the natural forest

SKILLS/PROCESSES

analysis, comparison

VOCABULARY

continua, continuum

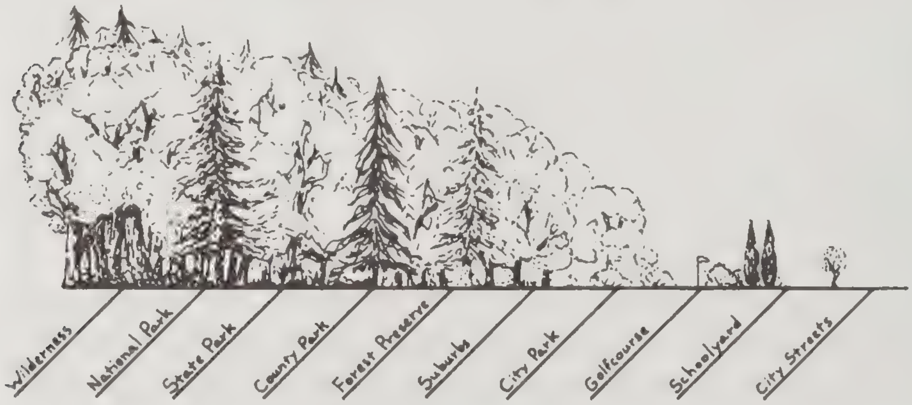
MATERIALS

colored pencils or crayons
multiple copies of **The Natural Forest** and **The Urban Forest**

PROCEDURE

1. Distribute copies of **The Natural Forest** and **The Urban Forest** and discuss them briefly. Note differences between the two using the Discussion Guide on the following page and details from the Background Information that precedes this activity. Students may color the the forest pictures and should be encouraged to add organisms they find appropriate. In addition, ask students to collect from magazines pictures of urban and natural forests. As a special project, a team of student photographers might document the local urban forest and a nearby natural forest.

2. Introduce the concept of a **continuum**. Natural forests are those in which human disturbance plays a minor role, for example, national parks, national forests, and forest preserves. Urban forests are those in which human disturbances such as roads and buildings are common, for example, suburban neighborhoods, school yards, and city parks. The degree of human disturbance varies along a continuum such as the one shown below. At one end is a National Wilderness Area, which by definition contains no roads or other disturbances; at the other end is a street in downtown Chicago, which may not have even a potted tree.



3. Conclude the activity by summarizing differences between the two forest types. Refer again to the Discussion Guide.

EVALUATION

Using the pictures assembled by the class, develop disturbance continua on the bulletin board or as poster presentations.

Discussion Guide

The Natural Forest	The Urban Forest
Trees	**Trees**
Trees are mostly native species that provide an abundance of nuts and acorns for wildlife.	There are many ornamental trees and shrubs of foreign origin.
Trees are spaced relatively close together.	Trees often have large spaces between them.
Dead standing trees provide homes for wood ducks, raccoons, woodpeckers, insects, and fungi.	There are few or no dead standing trees. Animals and plants that need dead trees for food or shelter cannot live here.
Decomposition of dead, fallen trees returns nutrients to the soil	Humans remove dead, fallen trees and add chemical fertilizers.
Forest Floor	**Forest Floor**
Forest floor is covered with trees, rotting logs, and other organic debris that provide habitats and food for fungi, insects, and other animals.	Ground is covered with pavement or mowed grass (usually a single species) and provides no shelter and very little food for animals larger than insects. Grass is often sprayed with pesticide.
Middle Layers	**Middle Layers**
Dense undergrowth and bushes provide safety and food for small, ground-feeding animals and other browsers.	Most bushes are non-native ornamental species that provide little food for animals. Bushes are often widely spaced.
Canopy Layer	**Canopy Layer**
Trees are close together and canopy is continuous. Tree-dwelling animals are able to move directly from tree to tree.	Canopy is very open due to large distances between trees. Tree-dwelling animals must cross pavement or grass to reach another tree.
Predators	**Predators**
There are many natural predators such as insects and small mammals like the fox and raccoon.	Cats, dogs, and humans are the major predators. There are fewer insect predators in urban forests than in the natural forest.

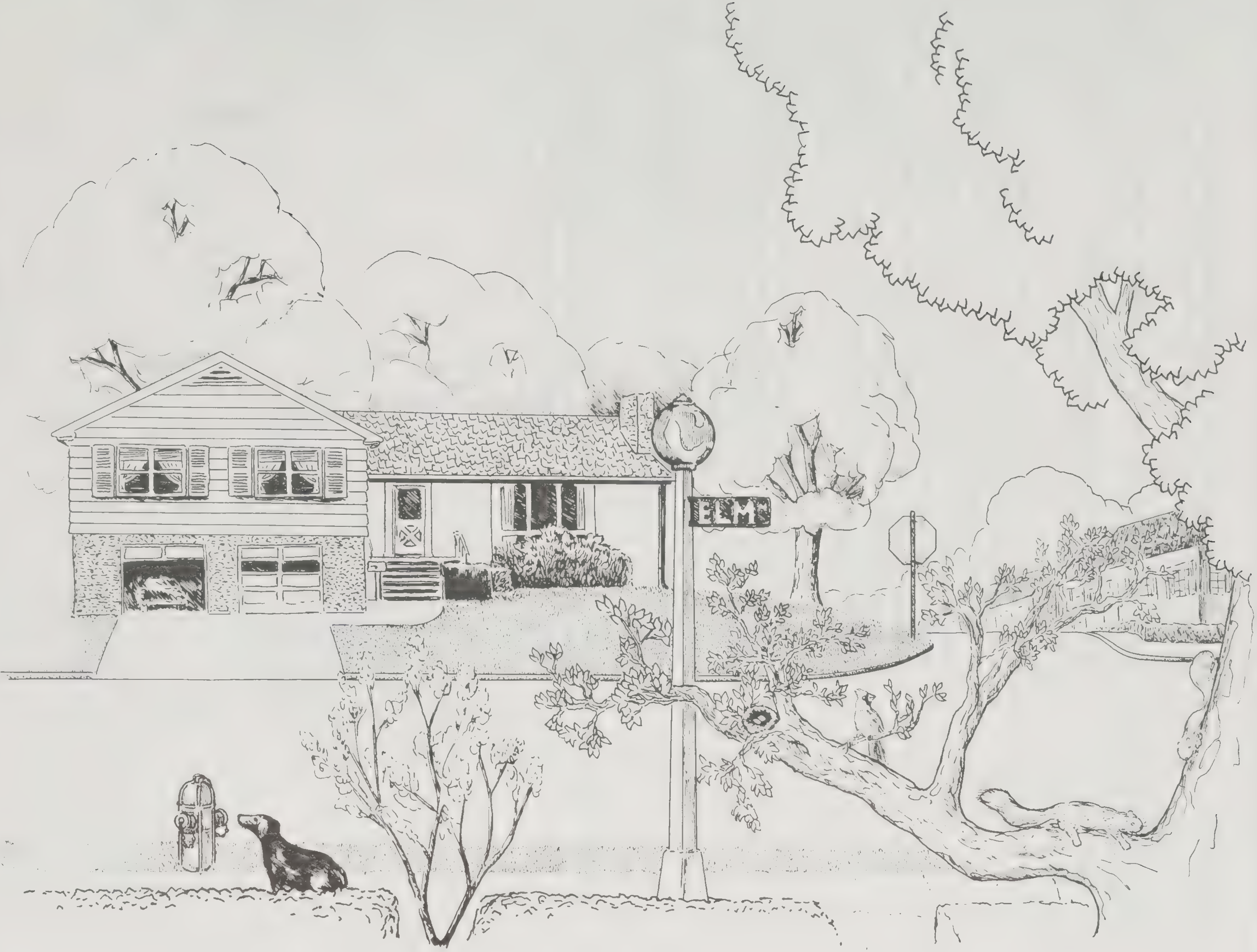
In general, more species of plants and animals are found in a natural forest that in an urban forest. Thus a natural forest has greater **species diversity** than an urban forest.

Questions to Consider:
What insects and other animals might fare better in the city? In the forest? Why? Can cars be considered predators?

Name:

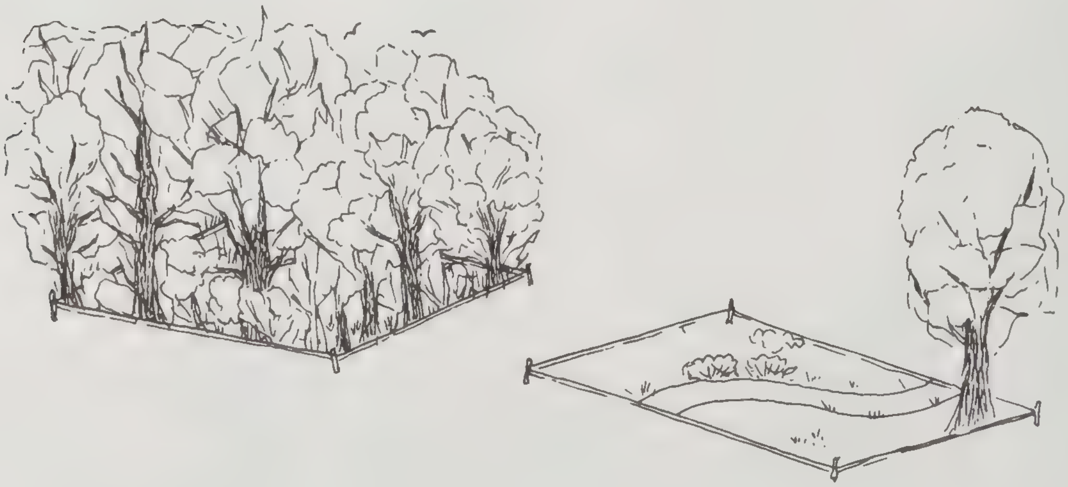
The Urban Forest

Name:



9.B Forest Inventories

OBJECTIVE	to apply to a field situation concepts learned in the classroom concerning the differences between urban and natural forests
SKILLS/PROCESSES	transfer of learning, observation, comparison, generalization
MATERIALS	multiple copies of **Inventory of Forest Species** tape measures, metersticks or yardsticks
PROCEDURE	1. Apply the concepts learned in the classroom in Activity 9.A by inventorying sample areas in natural *and* urban forests. Arrange a field trip to a nearby natural forest and ask students to do what biologists do when they study a habitat—take a "species inventory." Choose a 15m × 15m (50' × 50') area and have students complete the **Inventory of Forest Species**. Students may work individually or in small groups. Data should be compared back in the classroom and a single, composite inventory compiled. 2. Repeat the inventory for a 15m × 15m area in an urban forest—a school yard with trees, a city park, a suburban neighborhood. Compile the results back in the classroom. 3. Compare and discuss differences between the two inventories: density of plants at different levels, diversity of plant and animal species, and complexity.
EVALUATION	Working individually or in pairs, students write one or more paragraphs in which they distinguish the urban forest from the natural forest. If you teach older students, you may elect to introduce the rhetorical devices of comparison and contrast.



Inventory of Forest Species

Name:

	natural forest	urban forest
number of large trees (>6" diameter)		
number of small trees (<6" diameter)		
species of trees		
number of bushes		
number of smaller plants		
type of ground (choose one or more) wet soil, dry soil, covered with leaves, bare soil, covered with grass, covered with pavement		
number of sidewalks and streets in area		
number of buildings		
number of animals		
species of animals		

9.C

The Importance of Diversity: Dutch Elm Disease and Gypsy Moth Invasion

OBJECTIVE

to understand the importance of diversity in the urban and natural forests

SKILLS/PROCESSES

analysis, calculation

VOCABULARY

species diversity

MATERIALS

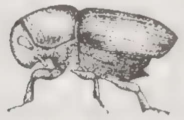
multiple copies of **Picture Sheets A, X,** and **Y**
multiple copies of **Preference Categories** from Activity 8.B
(If you prefer, list these categories on the chalkboard.)
colored pencils or crayons
several field guides to trees or other illustrated tree books

COMMENTS

Dutch elm disease was first found in the United States in 1909 in Boston, Massachusetts. Since its introduction from Europe, this disease has killed millions of elm trees throughout the country. It was first found in a single Illinois county in 1950. By 1959, it had spread to every county in the state.

The first noticeable symptoms of Dutch elm disease are wilting, curling, and yellowing of leaves on one or more branches. These symptoms are followed by the dying and early loss of leaves and the death of affected branches. Elms affected in this manner may die slowly over a period of one or more years. Some elms may show foliage wilting on most or all of their branches at one time and may die within a few weeks.

(magnified 7 times)


European elm bark beetle

native elm bark beetle

Dutch elm disease is caused by the fungus *Ceratocystis ulmi*. This fungus grows in the water-conducting vessels of the tree and causes brown discoloration of the sapwood. It may be transmitted to healthy elms by elm bark beetles or by grafted roots between diseased and healthy trees.

The insect carriers of the fungus in the United States are the European elm bark beetle and the somewhat larger native elm bark beetle. The European elm bark beetle feeds on bark in crotches of one- and two-year-old twigs during May and June. The fungus spores deposited in the feeding wounds grow and spread in the young sapwood. In time, leaves wilt and branches die. The fungus persists from year to year in the dead tree.

No species or variety of elm is known to be immune to Dutch elm disease, but the American elm (*Ulmus americana*) is the most susceptible. Although Chinese and Siberian elms are normally highly resistant to Dutch elm disease, trees of these species have succumbed to natural infection in Illinois.

The loss of trees along some streets in this country was an unfortunate occurrence that might have been avoided. If people had planted several different species of trees along their streets instead of only elms, some trees would have remained after the Dutch elm disease epidemic. While such a view is hindsight, we have learned from past mistakes that a diversity of trees in urban forests helps to assure that no one disease or pest will destroy them all.

PROCEDURE

1. Remind students that although urban forests and natural forests differ, the trees and other organisms found in a city constitute a forest community as do the organisms in a natural forest.

2. Distribute **Picture Sheet A** to each student. Ask students to count the number of elms and the total number of trees in each of the communities on Sheet A: natural forest, Main Street, and Park Street. Calculate together at the chalkboard the percentage of elms in each of the three communities and write this information on the board. How many different species of trees are in the natural forest community? How many are in the Main Street community? in the Park Street community? Which community has the greatest species diversity? Which has the least?

3. Using the information given in Comments, discuss the nature and spread of Dutch elm disease. Embellish this material with local history of the disease if possible. Then develop the following scenario based on the three communities shown in Picture Sheet A.

   > Dutch elm disease has infected all the elms in the natural forest and all of those on Main and Park streets. At the end of three years, all elms are dead.

   Eliminate the elms from the natural forest community and from the urban forest communities on Main and Park streets by blacking them out. Then color the remaining trees green.

4. Discuss the effects of Dutch elm disease with questions such as these: Which community has the least number of trees remaining? How did the disease affect the most diverse community? the least diverse community? Can those who plant urban forests reduce the effects of tree diseases like Dutch elm disease? How?

5. Distribute **Picture Sheet X** to each student. Does the natural forest community or the urban community on State Street have the higher diversity of species? Students will probably comment on the absence of elms on State Street; some may even express concern over the relatively homogeneous planting of oak trees. Does that portend trouble in the future or did the homeowners assume that oaks were resistant to disease? Capitalize on these questions as you move into the following scenario.

   > Ten years ago, a family moved to Illinois from Pennsylvania. They were unaware that gypsy moth egg masses had been laid on lawn furniture they brought with them. The following spring, the eggs hatched and began a new population of gypsy moths. Prior to this event, there had been no gypsy moths in this town. After five years, the gypsy moth population became exceedingly large on State Street and in the neighboring forest. During the fifth summer, all the trees preferred by gypsy moth caterpillars (**Preference**

Categories, Activity 8.B) were completely defoliated. The caterpillars defoliated these same trees for the next two years. Eventually three out of every four trees in the preferred category died; all trees in the intermediate and nonpreferred categories survived.

6. Students black out three out of every four preferred trees along State Street and in the nearby forest. Then they color the remaining trees green. How has the gypsy moth affected the State Street urban forest? the natural forest? What conclusions can be drawn about how urban forests should be planted? What speculations can be made about the future of natural forests after they become infested with gypsy moths?

EVALUATION

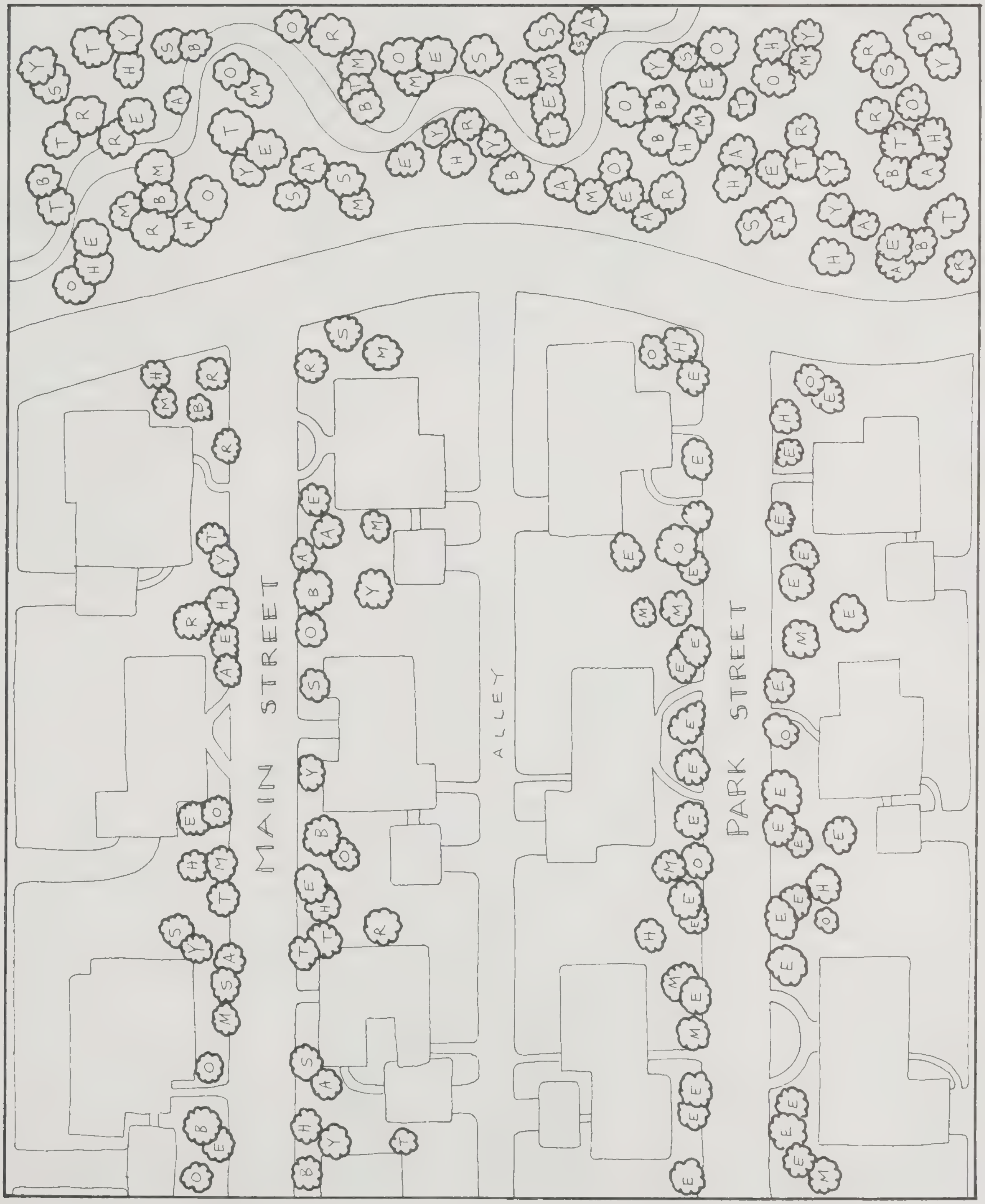
Distribute a copy of **Picture Sheet Y** to each student. Students replant the lots on State Street by referring to the gypsy moth **Preference Categories** (Activity 8.B), keeping in mind that Dutch elm disease and the gypsy moth are now members of the urban forest community. Students will need to make keys to represent each tree species shown on their sheets. Encourage students to refer to the field guides to trees in making their selections and to consider aesthetic characteristics of tree species as well as resistance to disease.

Picture Sheet A

Name:

Key

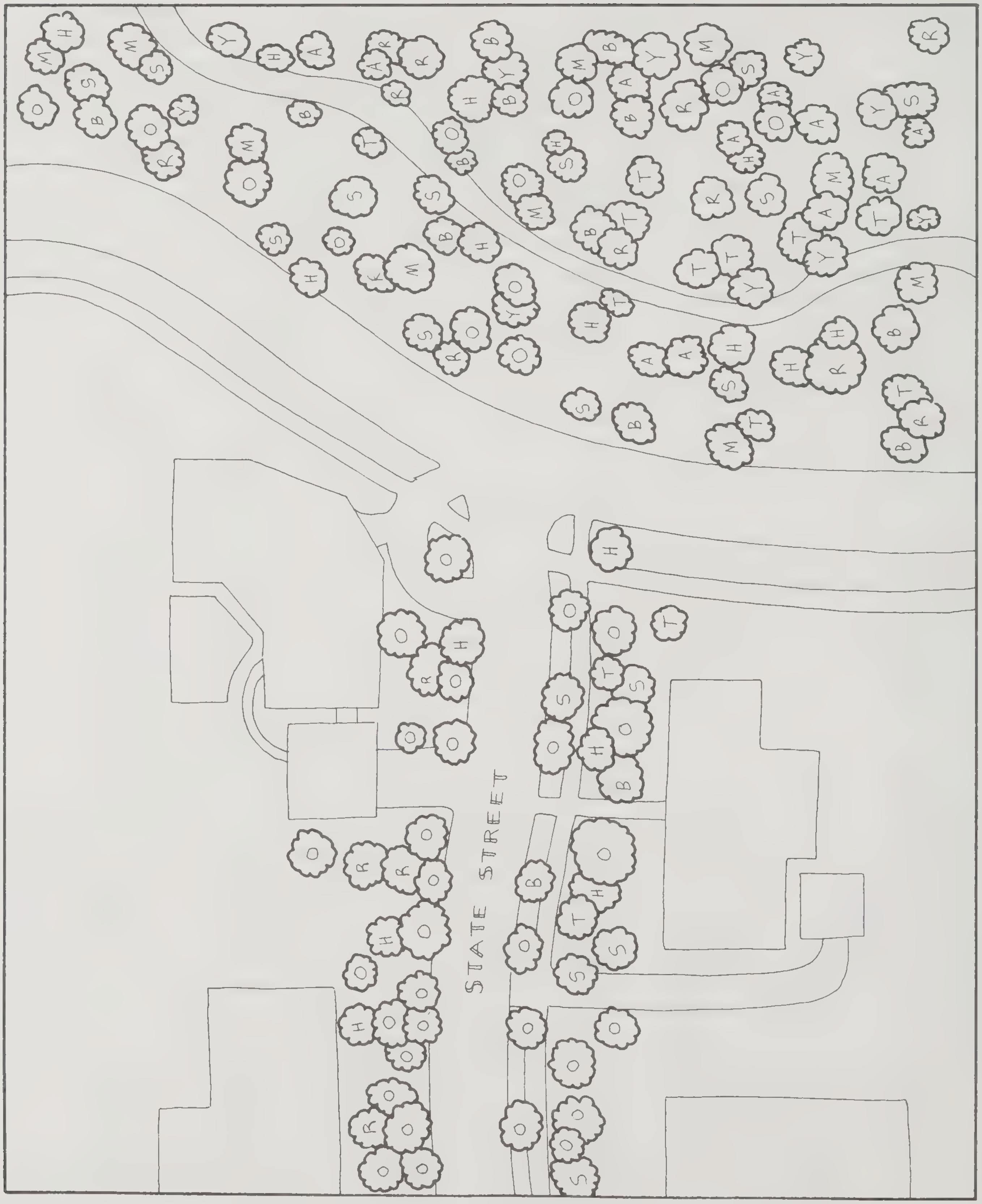
O	oak
R	birch
S	spruce
M	maple
B	buckeye
H	hickory
T	tulip tree
Y	sycamore
A	ash
E	elm



Picture Sheet X Name:

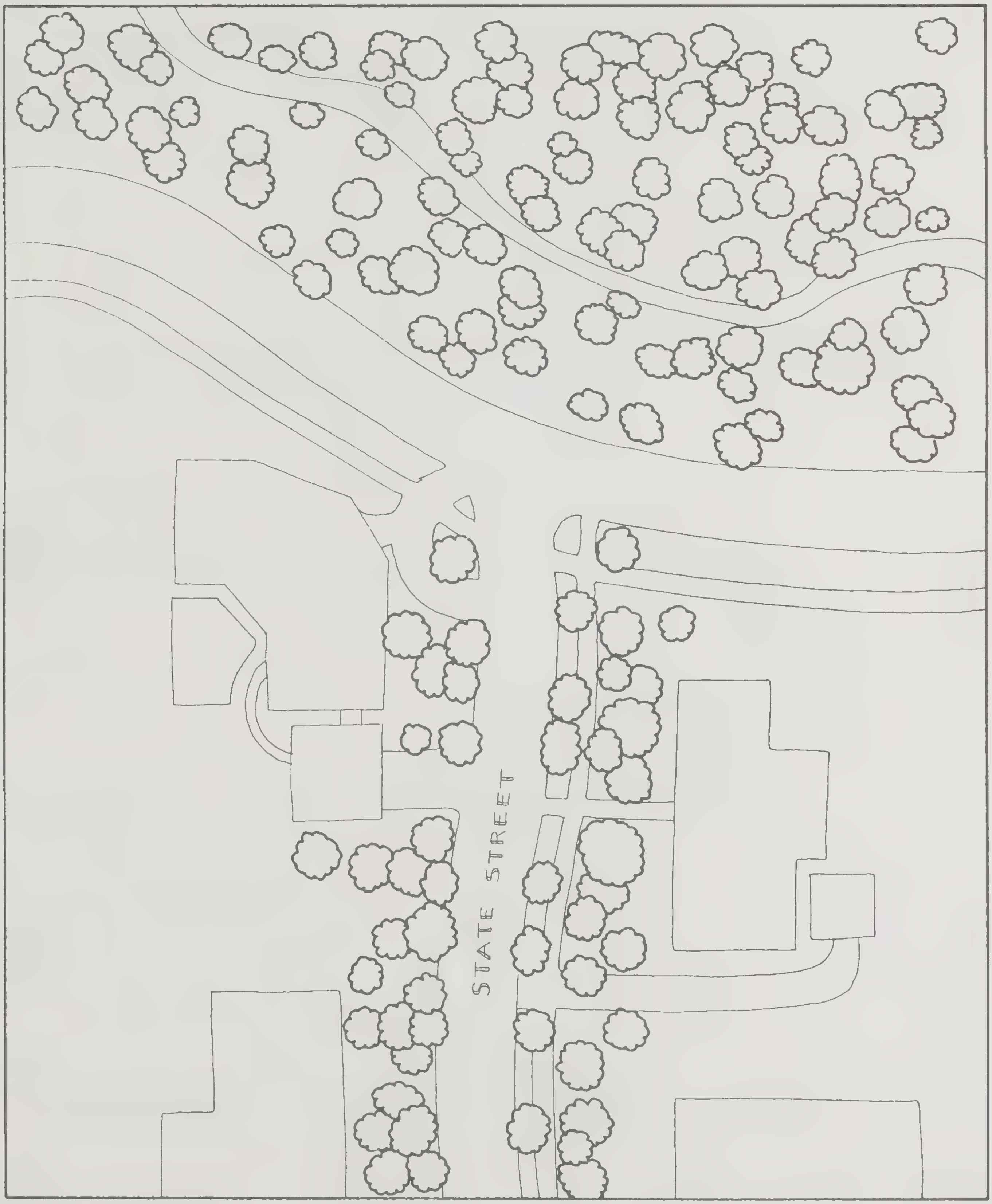
Key

O	oak
R	birch
S	spruce
M	maple
B	buckeye
H	hickory
T	tulip tree
Y	sycamore
A	ash



Picture Sheet Y Name:

Key



9.D Gypsy Moths in the Park

OBJECTIVE

to explore the impact the gypsy moth would have on a local park and its users

SKILLS/PROCESSES

application, observation, synthesis

COMMENTS

This activity is recommended for use in a local county or state park. If travel to such a place is impractical, try one of the following suggestions. Use a nearby city park and ask students to modify their hand-drawn maps by adding camping sites and wooded areas. Or, as an indoor activity, obtain a map of a local state park for use in this activity. Students may enjoy creating a fictional park on a poster or a three-dimensional model of a park, complete with stand-up trees and buildings.

MATERIALS

colored pencils or crayons
drawing paper
poster board (optional)

PROCEDURE

1. If you schedule this activity in spring, you may want to conduct it in a nearby park. Each student draws a map of the park, indicating wooded areas, campsites, picnic areas, playgrounds, parking lots, and other facilities.

2. Develop the following scenario.

   > The Smith family lives in Pennsylvania in an area that has high numbers of gypsy moths. Last year in early spring they took a cross-country camping trip that took them through Illinois. They camped with their trailer overnight in (*name of a local park with trailer sites*).

3. Pause in the narrative while each student draws in the trailer site used by the Smiths.

4. Continue the narrative.

   > The Smiths did not know that back in Pennsylvania gypsy moths had laid egg masses on the underside of their trailer. Neither were they aware that when they left the park in Illinois an egg mass had fallen off into the grass. That spring and summer no one noticed the gypsy moth caterpillars munching away on the oak trees near the campsite that had been used by the Smiths. In the autumn, no one noticed the velvety brown egg masses on the trees either. The next spring has now arrived, and the days are warming up.

5. Discuss together what effects low numbers of gypsy moth caterpillars will have on the Illinois park (few caterpillars visible, little defoliation, no disruption of activities in the park).

6. Resume the narrative.

> The gypsy moths in the park go undetected for three more years, and the population builds to high numbers.

Discuss the effects of high numbers of gypsy moth caterpillars on the park. How are the trees affected? How are the users of the park affected? Encourage a wide range of responses and list these on the chalkboard, for example, effects such as lack of shade, playground equipment and picnic tables crawling with caterpillars, and the expense of replacing dead and dying trees. Discuss how park planners and managers should minimize a gypsy moth problem by planting nonpreferred trees, monitoring for early signs of gypsy moths, and taking precautions against accidental introduction of gypsy moths. What techniques might park managers use to discover the presence of low numbers of gypsy moths in the park? How might users of the park help?

EVALUATION

Conclude the activity by asking students to draw a *before* and *after* view of the campsite used by the Smith family—the spring of their visit and the spring four years later. If there is time, these pictures can be combined with the map drawn earlier to make a bulletin board or poster display. The before and after views of the campsite can be treated as closeups of the site marked on the map and related to it with arrows, lines, or "blow-up" circles. Yarn or string may also be used to show these relationships.

9.E The Value of a Tree

OBJECTIVE to perceive the value of a tree

SKILLS/PROCESSES communication, establishing values

VOCABULARY aesthetic value, appraisal, appraiser, board foot

PROCEDURE

1. The class agrees on three species of trees for study, one from each of the preference categories of the gypsy moth (Activity 8.B). For example, white oak from the preferred category, maple from the intermediate category, and tulip tree (yellow poplar) from the nonpreferred category.

2. Appoint three students to complete the following telephone assignments.
    a. Call a tree nursery and obtain a price for each of the three tree species chosen by the class. Decide on a uniform size in advance, for example, 8–10 feet in height and balled and burlapped.
    b. Call a lumber yard and get a price per board foot for each of the three tree species. (Some species may not be available as lumber.)
    c. Call a real estate agent or a land appraiser and obtain values for three similar properties—one with mature trees, one with young trees, and one with no trees.

    Set aside an area of the chalkboard to record the information from these phone calls.

3. Discuss the environmental value of trees. List as many examples on the chalkboard as possible: shade, windbreak, cooling effect in summer, oxygen production, humus value of leaves, homes for birds and other animals, food for birds and other animals. Can a dollar value be placed on the environmental value of trees? Allow for differences of opinion. For example, shade may have an environmental value but it also has a dollar value if it lowers the cost of air conditioning your home.

4. Discuss the aesthetic value of trees. Why are trees important to us? What do we like about them? Why do they figure so importantly in painting and poetry? Consider the trees of Monet or Van Gogh, for example, or the metaphor of man and tree in Shakespeare's Sonnet 73 ("That time of year thou mayst in me behold, when yellow leaves, or none, or few do hang upon these boughs.") Why do we identify with trees? Why did early peoples assign spiritual significance to trees?

5. Discuss the economic value of trees. What do we use lumber for? Which species of trees are more expensive as lumber than others?

6. Discuss the impact of a major gypsy moth outbreak (total defoliation for several years in a row). You may wish to list the responses of students at the chalkboard and later categorize them by environmental, aesthetic, or economic values. For example, loss of trees means cost of replacement, decreased property values, loss of income to the owners of campgrounds. But the loss of income at a campground would be a result of the campers not liking the campground without its trees—an aesthetic reason. Trees that are affected but do not die may experience slower growth rates, thereby reducing or delaying their value as lumber. The ugliness of an affected tree may cause it to lose its aesthetic value. It is difficult to assign an economic value to the loss of songbirds and squirrels.

EVALUATION

List with the class as many words descriptive of trees as they can come up with in a stipulated time, perhaps four minutes. Encourage rapid responses so a stream-of-consciousness effect is achieved. For example, green, cool, shade, tall, summer, leaves, rustling, falling, winter, bare, branches, trunk, sturdy, mighty, towering. When the time limit is reached, ask students to use words from the list to create a poem describing a tree. The poem need not rhyme, and students may elect to write a picto-poem, a poem in which the shape reflects the silhouette of a tree. Words not on the class list may, of course, be added to the poem. For example,

y
o
u
r
clean
green
needles
bathed in sun
washed by dew and rain
clothed in snow and shadow
evergreen, evergreen, be ever green.

10. Pheromones and Detection: Background Information

When gypsy moths begin to colonize a new area, their numbers may remain low for several years. A small gypsy moth population may not be obvious to even a skilled arborist or entomologist.

Scientists, however, have discovered how to utilize a natural gypsy moth function (mating) to detect adult male moths. Female gypsy moths emit an air-borne chemical sex attractant, a **pheromone**, to attract males. The strong-flying male gypsy moth uses his feathery antennae (olfactory system) to detect the female's pheromone and to follow the trail directly to her. The two moths then mate, and the male flies to another pheromone-emitting female.

Synthetic gypsy moth pheromone is now produced commercially and used to trap male gypsy moths. Pheromone traps are made of cardboard, and the interior is coated with an extremely sticky substance. In the summer, traps are attached to trees, fences, and other vertical surfaces. Male gypsy moths follow the scent of the synthetic pheromone directly to the traps. When they enter, they become permanently stuck in the interior.

Pheromone traps have two functions, **detection** and **control**. **Detection traps** are placed at a density of one trap per square mile in such likely places as vacation spots, large urban areas, and industrial sites. (In Illinois, the State Department of Agriculture is responsible for detection trapping in likely areas.) The traps are checked regularly during the summer. When several males are caught in an area, females are assumed to be present and authorities may initiate gypsy moth control measures. **Control traps** are set at a much higher density than detection traps—1,920 traps per square mile! Because so many traps are set, authorities hope to catch most of the male moths before they mate. Control trapping is also called mass trapping and is usually done in conjunction with other control measures, such as the spraying of insecticides.

10.A Pheromones

OBJECTIVE	to learn what a pheromone is and how it functions
SKILLS/PROCESSES	application, observation
VOCABULARY	pheromone, pheromone trap, synthetic
MATERIALS	18 baby food jars with lids aluminum foil or black paint a punch or a sturdy nail and a hammer 6 items with distinct odors: mothballs, pine oil cleaner, garlic, slices of lemon, chocolate, perfume, vanilla extract, pepper, sage, ammonia multiple copies of **Pheromone Trap** scissors and cellophane tape

PROCEDURE

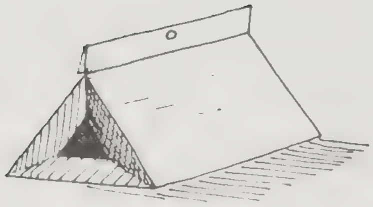
1. Cover each jar with aluminum foil or paint the jars black. Punch several holes into each jar lid. Place a sample of the first of the six items with distinct odors into three of the jars; replace the lids and number the jars 1, 2, and 3. Repeat for the remaining five items, numbering the jars consecutively from 4 through 18. Randomly place the jars about the room.

2. Write the name of each of the six items on a separate slip of paper.

3. Caution students in advance that this is a silent exercise and no talking or other communication will be allowed. Divide the class into six groups. Ask each student to list the numbers from 1 through 18 on a sheet of paper and to carry this list and a pencil throughout the exercise. Show each group one of the six slips of paper; this is the special odor for which they are to search; no other odor is of interest to them. Students then sniff the contents of each jar and place an X opposite the numbers on their lists that correspond to the numbers on the jars that they think contain the special item for which they are searching.

4. After the sniffing has concluded, reveal the contents of each jar by number so that students can check the accuracy of their noses. An accurate nose should have detected the same scent in three different jars.

5. Explain that a **pheromone** is a chemical message sent by one sex to attract a mate. Just as each classroom group had an assigned odor to locate, so do many insect species have a special scent to locate. Using details from the preceding Background Information, explain that this insect behavior has been used by scientists to design **pheromone traps**. Pheromone traps allow us to use the special scent of the female gypsy moth to determine if male moths are present in an area.



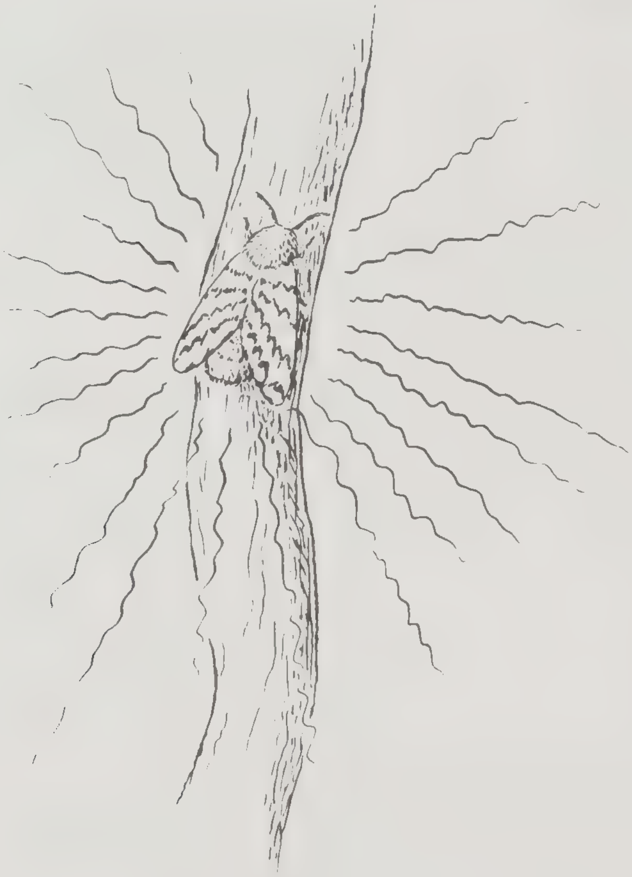
6. Distribute copies of **Pheromone Trap** so that each student can construct a trap. Explain that traps of this design are called delta traps because of the similarity in shape to the Greek letter delta (Δ). Remind students that an actual trap contains a synthetic pheromone and the interior is coated with a sticky material to capture the male moths. As students work, encourage a discussion of ways that other animals, including humans, attract the opposite sex, for example bird songs, bright feathers, behavioral displays, and "gifts" of food or nesting materials.

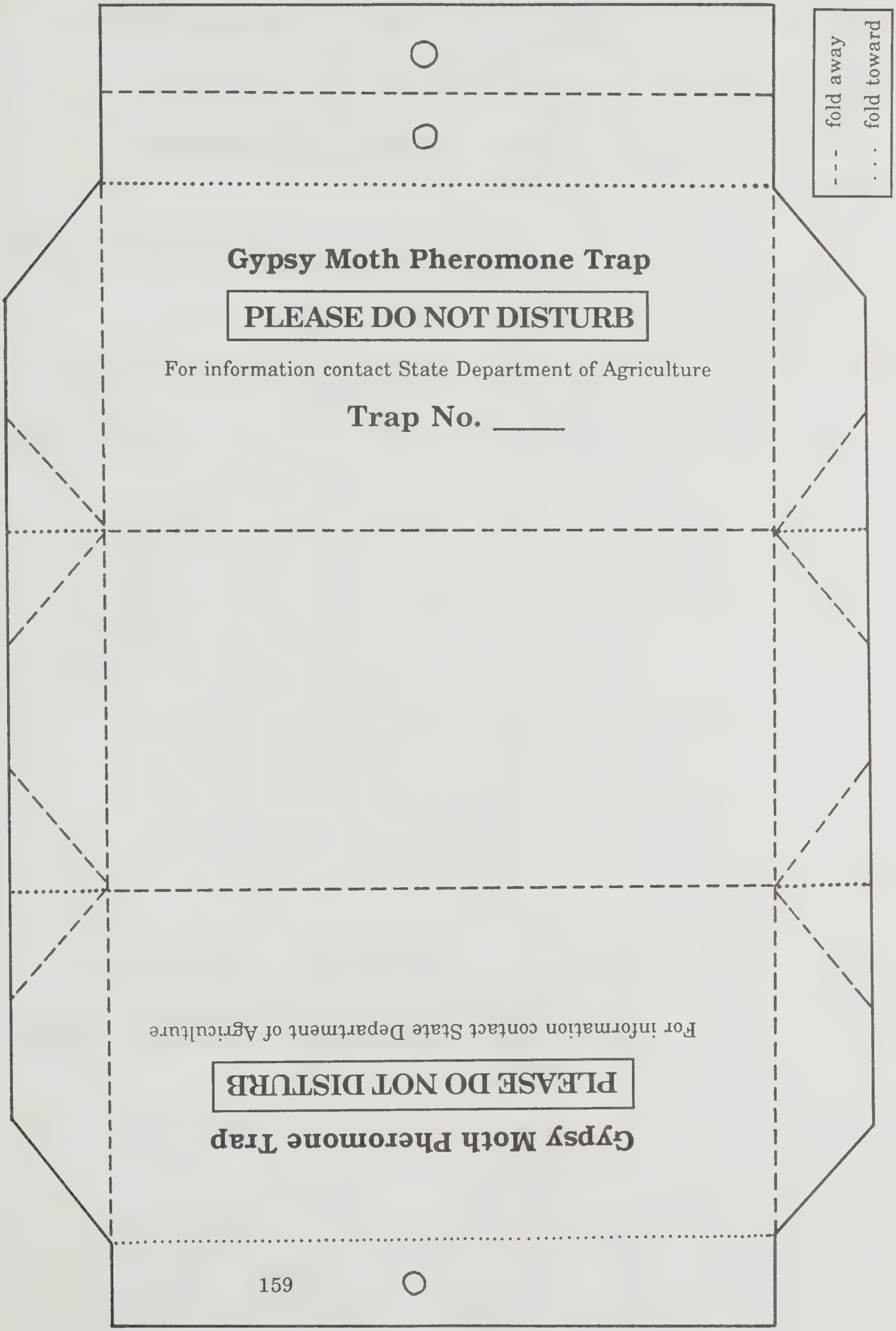
   NOTE: Save these traps for Activity 10.C: More about Detection of the Gypsy Moth.

EVALUATION

Allow about five minutes for students to complete the following written evaluation.

a. What is a pheromone?
b. Distinguish between detection and control trapping.
c. What are three essentials in constructing a pheromone trap?




Gypsy Moth Pheromone Trap
PLEASE DO NOT DISTURB
For information contact State Department of Agriculture
Trap No. ____
For information contact State Department of Agriculture
PLEASE DO NOT DISTURB
Gypsy Moth Pheromone Trap
- - - fold away
. . . fold toward

10.B Detection of the Gypsy Moth

OBJECTIVE

to understand the placement of pheromone traps for detection and control

SKILLS/PROCESSES

application, observation, simulation, extrapolation

VOCABULARY

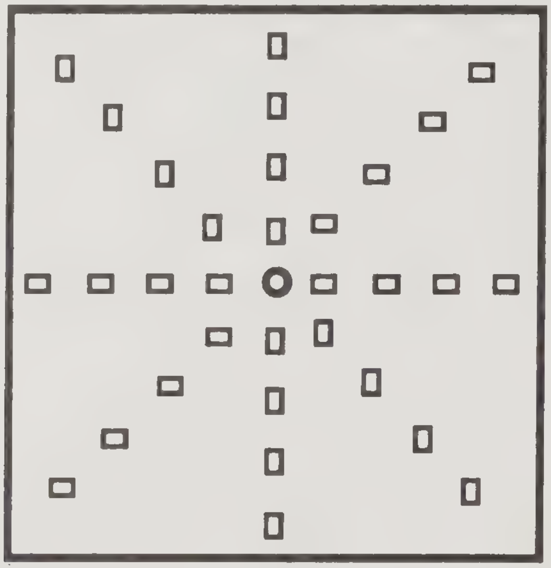
control trapping, detection trapping, extrapolate, grid

MATERIALS

a small jar with a lid
several cotton balls
a small amount of a substance with a distinct odor in an unmarked container (e.g., ammonia, perfume)
measuring tapes
small slip of paper for each student

PROCEDURE

1. Arrange student desks or ask students to stand or sit to form a square grid in the classroom as shown below. The distance between desks or students will depend on the size of the room, but 4 feet is a reasonable distance. Draw the grid on the chalkboard and use each student's initials to mark his or her place on the grid.



2. In another room, place the cotton balls in the jar and saturate them with the strong-smelling substance. Replace the lid immediately. Place the jar in the center of the grid in the classroom and remove the lid. (Do not prepare the jar too far in advance because the scent may escape. Also, be sure none of the odor lingers on your hands or clothes.)

3. Ask students to sit or stand quietly in their assigned positions and concentrate on detecting the scent coming from the jar. In a minute or two, distribute the slips of paper and ask students to write down their initials and whether or not they were able to smell the substance in the jar. If they can, they may also identify the substance. Collect the slips of paper.

4. Appoint several student tabulators to transfer the data from the slips of paper to the grid on the chalkboard. They may use a notation system of their own devising, such as placing an X on each grid position where a student was able to smell the substance. A double XX might indicate that the student correctly identified the substance.

5. Explain the purpose of **detection trapping** as presented in Section 10: Background Information. Discuss how this activity relates to the detection trapping of gypsy moths. Working as a group, compute the area covered by the odor by measuring the distance from the center of the grid to the positions of students farthest from the center who were able to detect the odor. Then compute how many jars would be needed to "trap" every student on the grid. Place an asterisk on the grid to represent where each of these jars should be located. Finally, calculate how many jars would be needed to cover a grid one acre in size.

6. Discuss these results with respect to the **control trapping** of male gypsy moths with synthetic pheromone. Traps must be placed so that at least one trap will attract any male in the area. How large a task is the placement and monitoring of traps? What effect might the presence or absence of wind have on control trapping?

EVALUATION

Imagine that the jar used in this activity was a pheromone trap for gypsy moths and that each student was a male moth. Answer the following questions in writing.

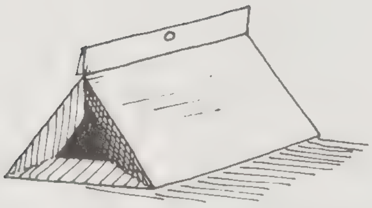
a. How many "moths" were attracted to the trap?
b. What percentage of the total population of "moths" was attracted to the trap?
c. How many traps would be necessary to attract every "moth" in the classroom?
d. Extrapolate the results of this computation to Trail of Tears, an Illinois state forest that has 3,870 acres.
e. How does control trapping differ from detection trapping?

10.C More about Detection of the Gypsy Moth

OBJECTIVE	to learn about detection trapping through simulation
SKILLS/PROCESSES	inference, observation, record keeping
VOCABULARY	focus, infestation
MATERIALS	10 or more pheromone traps from Activity 10.A several copies of **Male Gypsy Moths** scissors glue multiple copies of **Trap Map** red crayons

PROCEDURE

1. Appoint a student committee to cut out several sheets of moths and glue them inside the traps made earlier in Activity 10.A. Instruct them to glue 15 to 20 moths inside each of two or three traps, 4 or 5 moths inside several others, 1 or 2 inside several others, and no moths in a couple more. The traps should then be numbered consecutively without reference to their contents.



2. Just prior to the class period place the traps around the school yard—on trees, shrubs, playground equipment, and fences. If the weather is inclement or the school yard inappropriate, use a large open area in the building such as the gym or the library. If necessary, use the classroom. The traps containing the largest numbers of moths will be the **focus** of the infestation and should be placed near each other. The remaining traps should radiate out from this center of density, with the traps containing the least number of moths (or no moths) placed farthest from the focus.

3. Begin the activity by briefly reviewing how pheromone trapping works (Activity 10.A) and how detection trapping differs from control trapping. Explain that the class will now carry out a simulation of a detection trapping program to detect gypsy moths, albeit paper ones, on school property.

4. Divide the class into as many groups as you have traps. Each group is responsible for retrieving one trap from the school yard and carefully noting the location of the trap.

5. When students have returned to the classroom, draw a map of the school yard on the chalkboard. A member of each group comes to the board and marks where its trap was located.

6. Students then open the traps and count the number of male gypsy moths inside. Write this number on the board adjacent to the location of each trap. Discuss where the focus of the moth infestation is located. If control measures are to be taken, where should they be initiated?

EVALUATION

Distribute a copy of **Trap Map** to each student. Explain that the map indicates the number of male gypsy moths trapped in one summer in an area where pheromone traps had been placed at a density of one per square mile. Ask students to use red crayons to indicate the following:

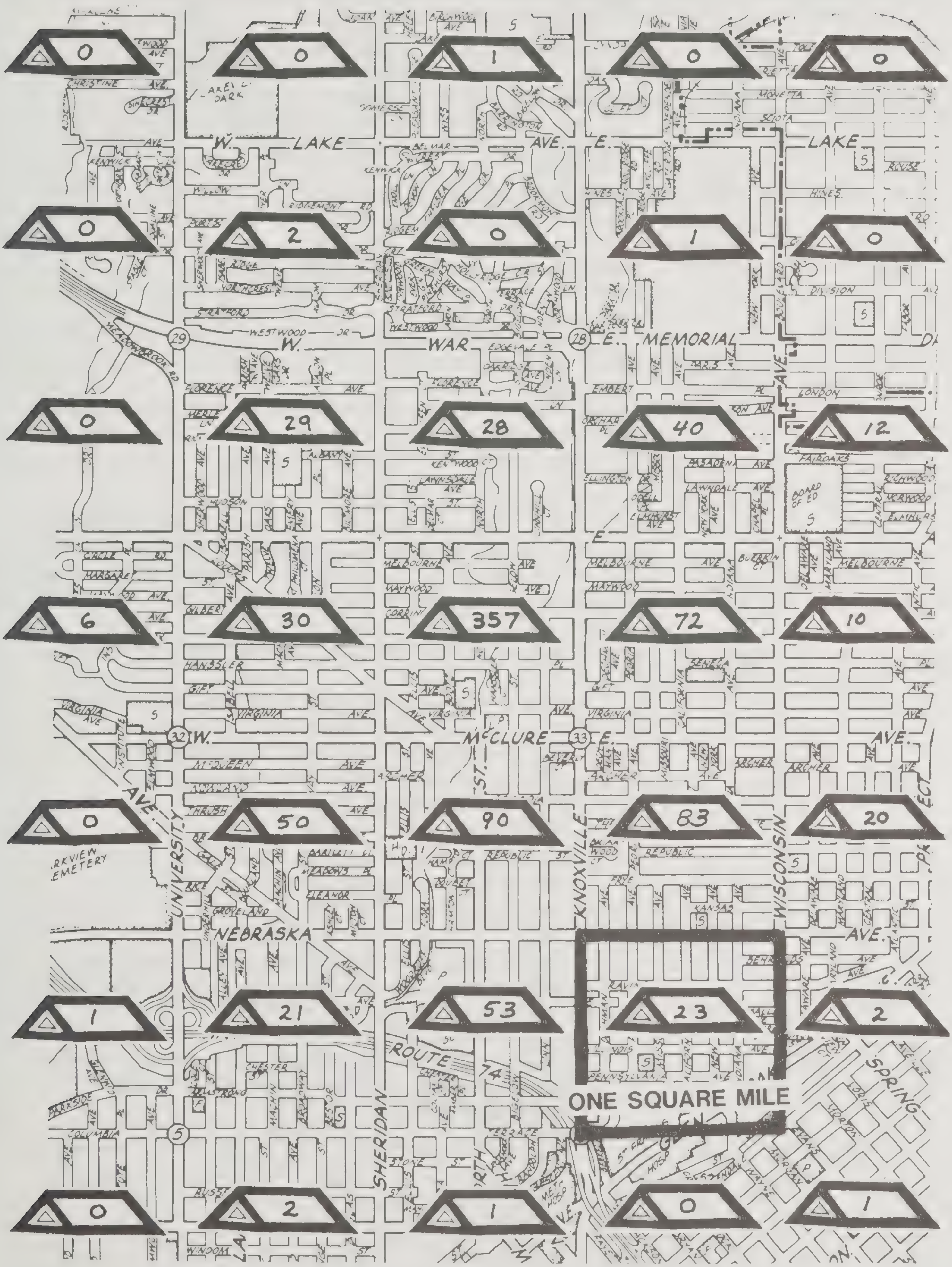
a. Indicate in red where the focus of infestation appears to be.

b. Outline in red the area you would choose if you have only enough funds to control gypsy moths in 10 square miles.

Male Gypsy Moths

Trap Map

Name:



10.D The Gypsy Moth in Illinois

OBJECTIVE	to learn where in Illinois the gypsy moth has been found
SKILLS/PROCESSES	application, deduction, computation
MATERIALS	multiple copies of **Gypsy Moth Trap Catches** and **County Map of Illinois** several road maps of Illinois colored pencils or crayons

PROCEDURE

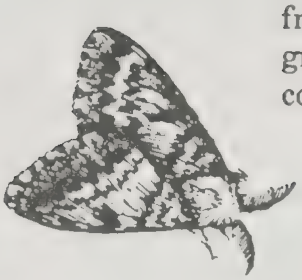
1. Distribute copies of **Gypsy Moth Trap Catches** and **County Map of Illinois** and ask students to total the number of male moths trapped in each Illinois county from 1973 through 1986. Take a moment to reach agreement on the answers before students enter these numbers by county on the map.

2. Using an Illinois road map as a reference, students locate major cities of Illinois and transfer these to their county maps. They also indicate their own city or community.

3. As a class, students agree on a color code to represent the densities of trapped gypsy moths, for example, red for counties in which over 1,000 moths were trapped, yellow for counties in which 500–999 were trapped, and so on. Students then transfer this key to their maps and color the counties accordingly.

4. Referring to the color-coded county maps, discuss issues such as these.
    a. What do the areas of highest density have in common? (Largest numbers are trapped near urban centers.) Why has the gypsy moth been found primarily in urban areas? (Movement of vehicles and people increase the likelihood of introduction from an infested area.)
    b. If only enough money and personnel were available to control trap in 30 Illinois counties, which counties would you choose? Why? Outline these counties on the map.
    c. Why is it important to detect gypsy moth populations when their numbers are relatively low and confined to small areas? (Focus or center of infestation is more readily located; relatively little damage has been done to trees; easier and less expensive to implement a control program in a smaller area; adjacent areas may be spared.)

5. Choose one of the following counties from the list below, and plot the number of gypsy moths trapped in that county each year from 1973 through 1986. Draw a line between the points on the graph. What year was the gypsy moth introduced into that county?



Lake County
DuPage County
McHenry County
Peoria County

EVALUATION

Why do you think the county in which we live has the density of trapped gypsy moth males shown on the map? Answer in a paragraph.

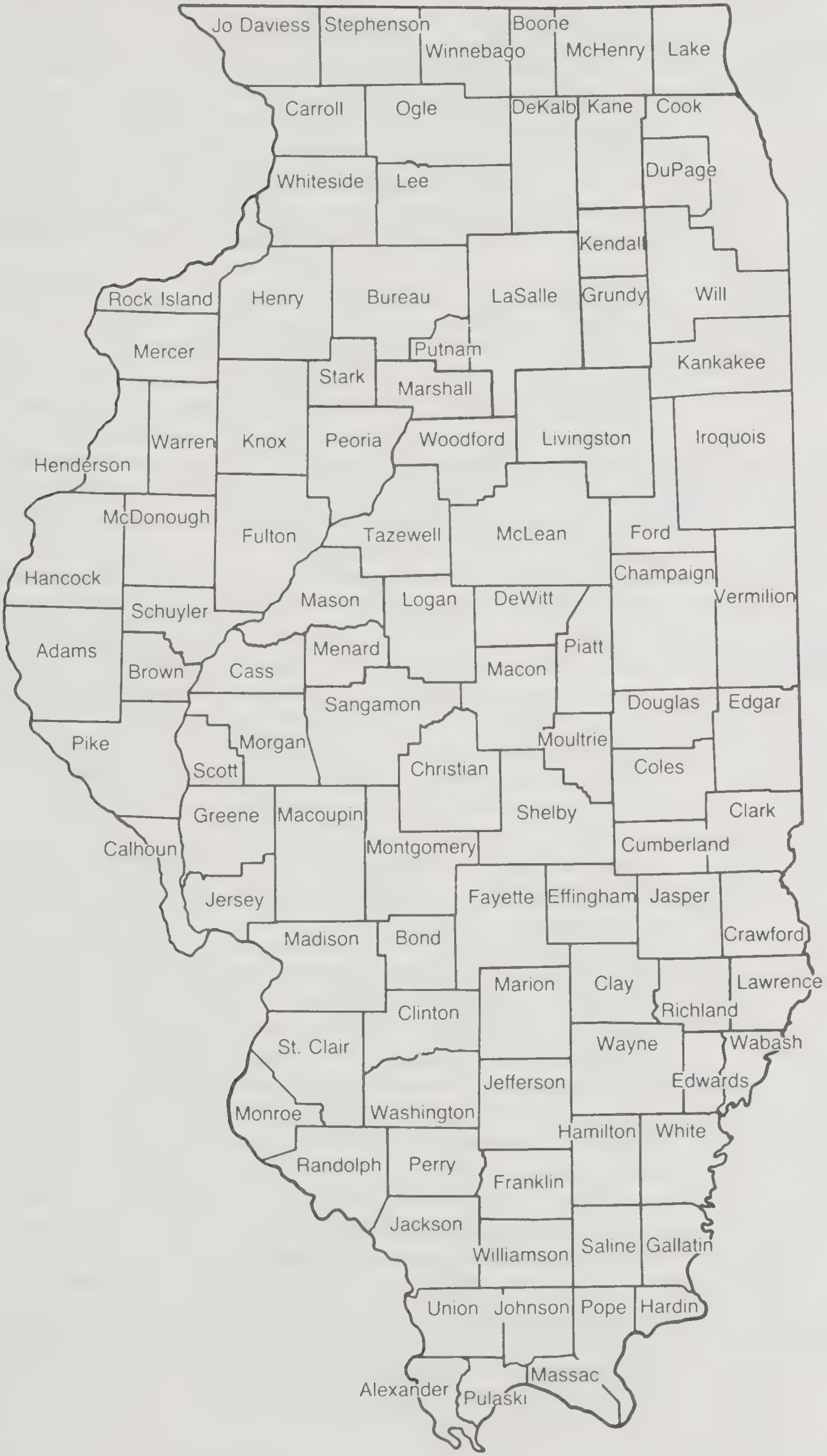
Gypsy Moth Trap Catches

Number of male gypsy moths trapped in Illinois by year

1973	2	Cook County
	1	Rock Island
	1	Sangamon County
	1	Will County
1974	12	Cook County
1975	191	Cook County
1976	1	Cook County
1977	2	Cook County
1978	2	Cook County
	6	Lake County
	9	McHenry County
1979	1	Cook County
	2	DeKalb County
	1	Henry County
	1	Jefferson County
	51	Lake County
	167	McHenry County
1980	1	Bureau County
	2	Dekalb County
	173	DuPage County
	5	Kane County
	149	Lake County
	83	McHenry County
	1	Tazewell County
1981	4	Champaign County
	43	Cook County
	1	DeWitt County
	2149	DuPage County
	1	Fayette County
	17	Kane County
	361	Lake County
	1	Marion County
	2	McDonough County
	52	McHenry County
	1	Peoria County
	1	Rock Island County
	3	Tazewell County
	3	Will County
1982	1	Bureau County
	2	Champaign County
	35	Cook County
	404	DuPage County
	42	Kane County
	6	Kankakee County
	92	Lake County
	1	LaSalle County
	16	McHenry County
	1	McLean County
	2	Will County
1983	1	Champaign County
	46	Cook County
	53	DuPage County
	44	Kane County
	68	Lake County
	3	McHenry County
	1	McLean County
	1	Winnebago County
	15	Peoria County
1984	7	Cook County
	13	Kane County
	3	DuPage County
	4	Lake County
	199	Peoria County
1985	2	Cook County
	4	DuPage County
	1	Kane County
	23	Lake County
	1	McHenry County
	1	McLean County
	1	Peoria County
	1	Rock Island County
	1	Whiteside County
	2	Will County
1986	8	Cook County
	7	DuPage County
	27	Lake County
	1	McLean County
	1	Peoria County
	1	Will County

County Map of Illinois

Name:



11. Chemical, Cultural, and Biological Controls: Background Information

To "control" an insect pest means to keep its numbers below a level that causes significant damage to crops or annoyance to people. Control methods vary, and choosing the best method for a particular pest requires knowledge of the pest's biology and an understanding of the consequences of using a particular method. Let's examine the major methods currently available to combat insect pests: chemical insecticides, microbial insecticides, biological control, and cultural control.

Chemical insecticides may be synthetic or natural. Synthetic insecticides are often produced from petroleum products. Sevin® and malathion are examples of synthetic insecticides. Natural insecticides are derived from natural plant products. Rotenone®, derived from a type of legume, and pyrethrins, derived from chrysanthemums, are examples of natural insecticides.

Microbial insecticides are produced from microorganisms that have toxic effects on insects. An example of a microbial insecticide is Bt (*Bacillus thuringiensis*), a bacterium that breaks down the digestive system of most caterpillars.

Biological control uses natural enemies to keep pest numbers down. Natural enemies include predators, diseases, and parasites. If an insect is introduced from another country and its natural enemies are left behind, it often becomes a pest in the new location. Natural enemies, however, can be imported; if they become established in their new home, they help provide biological control.

Cultural control renders particular environments unfavorable for pests and is primarily used in agriculture. Crop rotation, modified tillage practices, and the careful timing of planting or harvesting are common cultural controls.

Each method of control has strengths and weaknesses. Chemical insecticides, for example, may reduce a pest population quickly, but what happens if some insects are resistant to the insecticide and continue to reproduce? What are the environmental consequences of using chemical insecticides? For the farmer, does the benefit outweigh the cost? The relationship of cost to benefit, effectiveness, reliability, and human and environmental hazards are among the factors that must be considered before choosing a method of control.

Many methods are available for controlling gypsy moths, and a threatened state usually develops guidelines for the control of this pest. When a community in Illinois is found to have gypsy moths, a public meeting is scheduled. Representatives from the Illinois Department of Agriculture and from the United States Department of Agriculture present an overview of the problem to city and/or county officials and provide information on the control options. Public reaction is requested, and all views on the choice of control methods are considered. The current recommendation for control in Illinois is the use of the microbial insecticide Bt in conjunction with a type of cultural control called mass trapping. (See Section 10 for more information on mass trapping.)

11.A Introduction to Insect Control

OBJECTIVE

to conclude that the methods used to control an insect depend on such factors as whether or not the insect is considered to be a pest, the number of insects present, and the environment in which the insects live

SKILLS/PROCESSES

evaluation, deduction, drawing inferences

MATERIALS

multiple copies of **Picture Pairs for Insect Control**

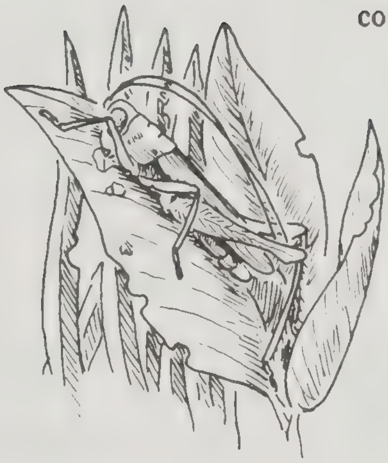
COMMENTS

This activity should be considered a preview assignment that will help you to determine the preconceptions, misconceptions, and accurate information that students have about how and why insects should be controlled. In subsequent activities students will enlarge and refine this information base.

PROCEDURE

1. Distribute a copy of **Picture Pairs for Insect Control** to each student. Without prior discussion, ask students to consider each picture pair and to jot down answers to the following questions:
    a. Would you kill the insect pictured here? Why or why not?
    b. How would you kill the insect in this picture?
    c. Is this insect a pest? Why or why not?

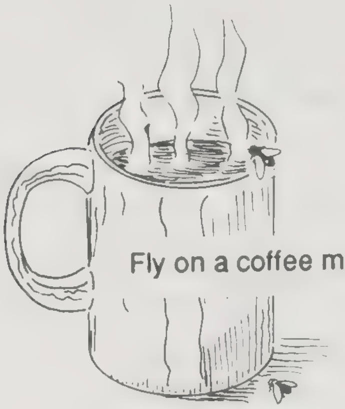
2. Discuss the answers students have given. Have they tended to recommend killing each insect regardless of the environment in which it was found or have they tended to make a yes/no distinction between each picture pair? Provide enough information so that students are able to reach the following conclusions.
    a. An insect is considered a pest only when it interferes with humans in a significant way, for example, an individual insect that carries disease or a population of insects that destroy crops.
    b. Insects that are pests in certain environments may not be considered pests in a different environment. Fleas in your home or on your pet are considered pests, but fleas on wolves in Minnesota are not considered pests.
    c. The methods required to control insects differ depending on the situation. You can swat a few mosquitoes in your home, but you can't kill all mosquitoes in a marsh using this method.



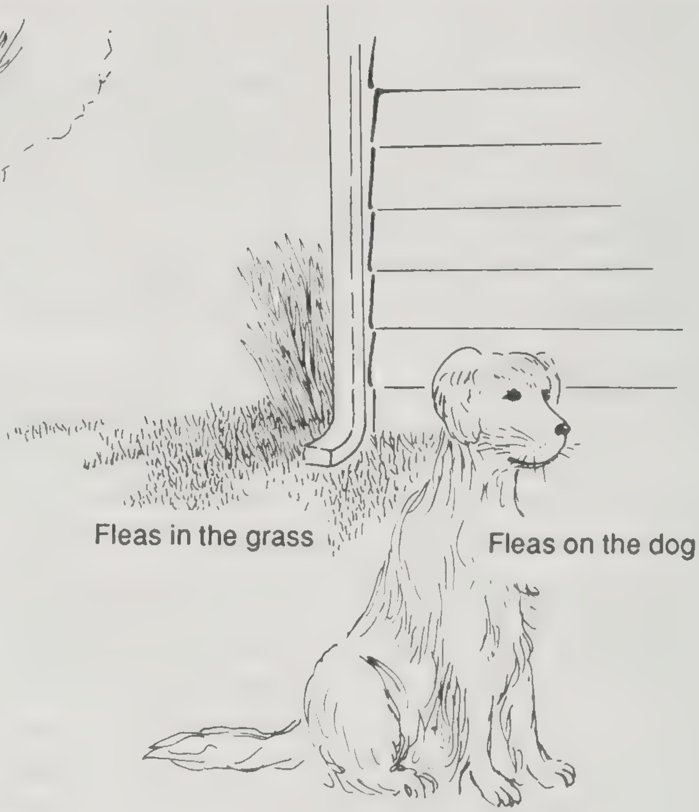
EVALUATION

No evaluation is required because the intent of this activity is to determine the information students bring to a problem, not the information they have acquired. You may, however, ask students to choose an insect and describe on the back of the picture sheet a setting in which that insect is a pest and another in which it is not. The description may be drawn or in writing.

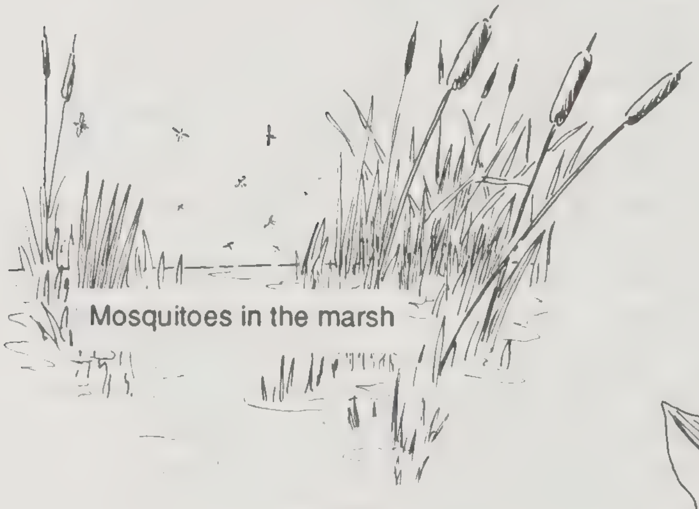
Picture Pairs for Insect Control


Fly on a coffee mug

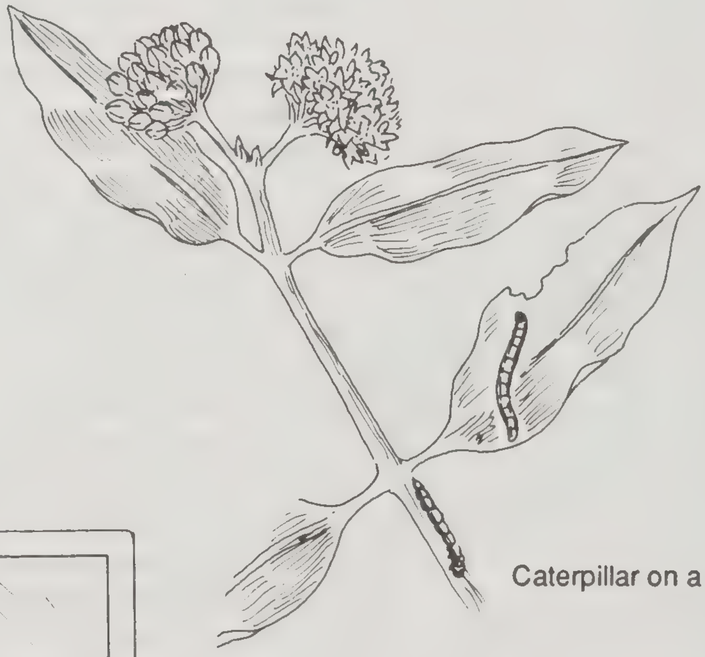
Fly on a tree trunk

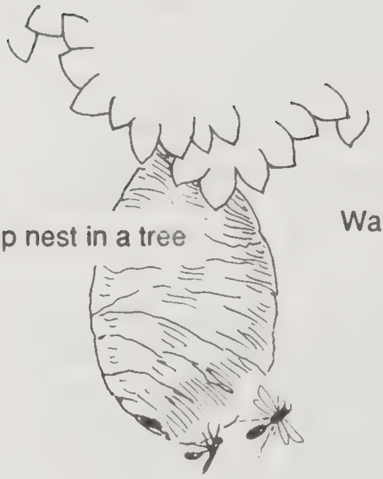

Fleas in the grass

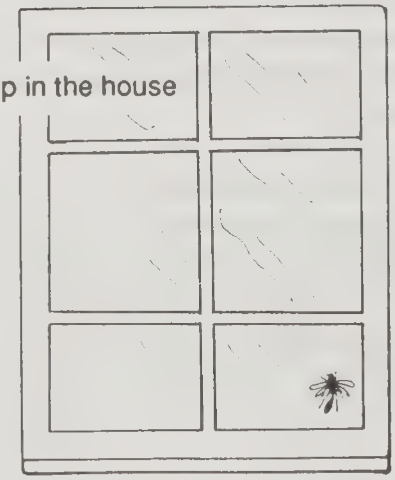
Fleas on the dog


Mosquitoes in the marsh

Mosquitoes biting your hand


Caterpillar on a prairie plant


Wasp nest in a tree


Wasp in the house

Clothes moth caterpillars in your clothing drawer

11.B History of Insecticides

OBJECTIVE

to learn what insecticides are and to follow their development and use through history

SKILLS/PROCESSES

measurement, historical perspective

VOCABULARY

insecticide, pesticide, synthetic

MATERIALS

multiple copies of **Insecticide Fact Sheet** (If you prefer to complete this activity as a group, write this information on the chalkboard.)
rulers
a paper roll from an adding machine, or paper and cellophane tape

COMMENTS

Pesticides are chemical substances used to kill or control pests. Various words ending in -icide designate different classes of pesticides. For example, an insecticide kills insects, an herbicide kills weeds, and a fungicide kills fungi.

With the discovery of DDT in 1939, the door was opened to the modern age of synthetic chemical insecticides (see Activity 11.G for more on DDT). These relatively inexpensive chemicals revolutionized agricultural practices and are now an integral part of modern agriculture. With increased reliance on insecticides and herbicides, the American farmer's productivity greatly increased.

In addition to their agricultural uses, insecticides have been used effectively in the fight against human and animal diseases carried by insects. The prevalence of such insect-borne diseases as typhus, yellow fever, and sleeping sickness has decreased since the advent of synthetic chemical insecticides. Malaria, which is carried by mosquitoes, killed 6.5 million people in 1939; in 1976, 2.5 million people died from malaria. In recent years, however, mosquitoes resistant to chemical insecticides have developed, and the number of malaria cases is currently increasing throughout the world.

PROCEDURE

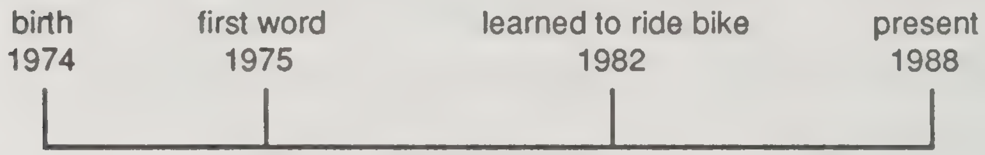
1. Define the following words for the class:

insecticide–a chemical substance used to kill insects

pesticide–a general term applied to substances that kill such pests as insects, rats, fungi, and bacteria

synthetic–a substance that is not produced in nature but is made by combining chemical compounds, for example, some insecticides, plastics, and nylon

2. Introduce the concept of a time line by sketching quickly at the chalkboard a time line for a typical student in your class. Ask students to contribute dates and events of major importance. For example, birth, first steps, first word, entered kindergarten, learned to ride a bicycle, etc., up to the present time.



sample time line

3. Distribute copies of **Insecticide Fact Sheet** and segments from the roll of adding machine paper. Each student constructs an insecticide time line using the information from the fact sheet. Students will need to determine an appropriate scale, perhaps each inch to indicate 500 years. As reference points, students may include significant dates such as those shown below.

1492	Columbus discovers the New World
1776	Declaration of Independence signed
1865	End of the Civil War
1914	Beginning of World War I
1945	End of World War II
1963	President John F. Kennedy assassinated
1968	Martin Luther King assassinated
1969	First person to walk on the moon
1976	American Bicentennial celebration
1986	Statue of Liberty 100 years old
1987	U.S. Constitution 200 years old

If you prefer, construction of the time line can be a class project at the bulletin board. A much larger scale can be employed, and the time line can be 5 or more feet long.

EVALUATION

The completed time lines serve as the evaluation for this activity.

Events in the History of Insecticide Development

During his travels in 1275 A.D., Marco Polo reported the use of mineral oil to treat camel mange, which is caused by tiny arthropods called mites.

Homer, in his writings from the year 1000 B.C., mentioned "pest-averting sulphur."

In 1800, the Persians used a substance called pyrethrum (pie-REATH-rum), which is obtained from the flowers of the chrysanthemum, to control fleas.

In 1972, DDT was banned in the United States because studies showed it to be an environmental hazard.

Cato reported in 200 B.C. that fumes of boiling mineral pitch or asphalt rid grape leaves of insect pests.

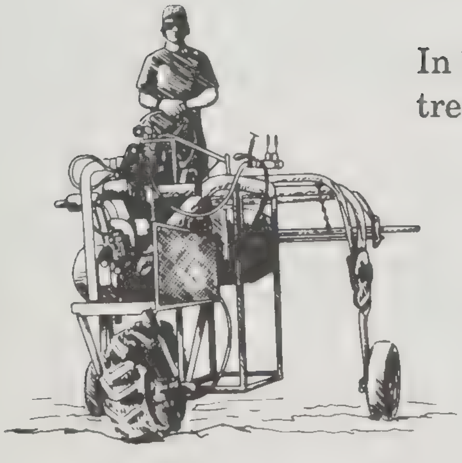
Dioscorides, in 60 A.D., reported the use of arsenic to kill pests.

Beginning in 1867, an arsenic compound called paris green became widely used to control many different kinds of insects.

Today most chemical insecticides used to control pests are synthetic.

DDT, the first of many synthetic chemical insecticides to be produced, was developed in 1939.

In 1690, mixtures of tobacco products were applied to pear trees to control pear lace bugs.



11.C Toxicity: Crickets

OBJECTIVE

to understand how toxicity is measured

SKILLS/PROCESSES

observation, analysis, calculation, graphing

VOCABULARY

LD_{50} (lethal dose), toxicity, toxin

MATERIALS

10 small babyfood jars with lids
cotton
vinegar
fingernail polish remover
2 eyedroppers
50 live crickets (available from pet stores year-round)

COMMENTS

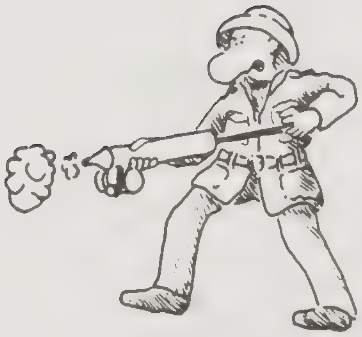
This activity results in the death of crickets. If you or your students find this experiment unacceptable, the concept of toxicity can be taught by presenting the results given in Step 8.

PROCEDURE

1. Cover the bottom of each babyfood jar with a layer of cotton about 1/2" deep. Label the jars as shown below and place the specified number of drops of vinegar or nailpolish remover into each jar. Immediately replace the lids.

jar label	no. drops vinegar
V-0	0
V-3	3
V-6	6
V-9	9
V-12	12

jar label	no. drops nailpolish remover
N-0	0
N-3	3
N-6	6
N-9	9
N-12	12



2. Explain that a toxin is a substance that can harm or kill a living organism, and that toxicity refers to how toxic a chemical is to organisms. Then announce that the class is going to observe a toxin at work.

3. Divide the class into ten groups, and assign each group to observe one of the ten jars.

4. Place four crickets into each jar and replace the lid. Each group of students observes the crickets in its assigned jar and after five minutes records the number of dead crickets. During this observation period, reproduce the following chart on the chalkboard.

vinegar

label	no. drops	no. crickets dead	% dead
V-0			
V-3			
V-6			
V-9			
V-12			

nailpolish remover

label	no. drops	no. crickets dead	% dead
N-0			
N-3			
N-6			
N-9			
N-12			

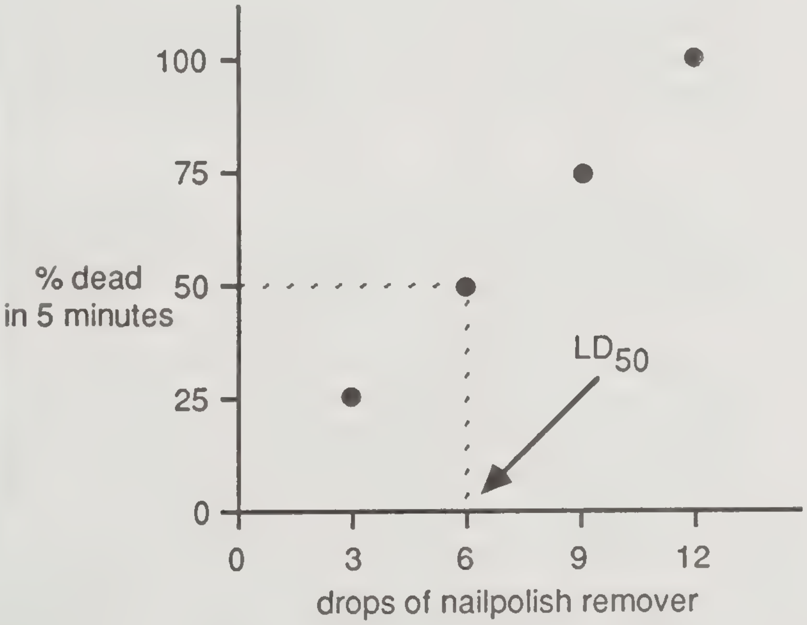
5. Each group then converts the number of dead crickets in its jar to the percent dead in that jar. If, for example, 2 crickets died in jar V-9, the percent dead = 2/4 or 50%. Insert these values on the chart. Complete the chart by filling in the number of drops in each jar.

6. Is vinegar toxic to crickets? Is nailpolish remover? Since only the polish remover proved toxic, the vinegar data can be set aside. Students then graph the nailpolish remover data as shown in the following example.

7. How many drops did it take to kill 50% of the crickets? This dosage is called "LD_{50}"; LD stands for "lethal dose" and 50 stands for "50 percent." Thus LD_{50} means the dose at which 50% of the crickets died. What is the LD_{50} of nailpolish remover for crickets?

Example: nailpolish remover

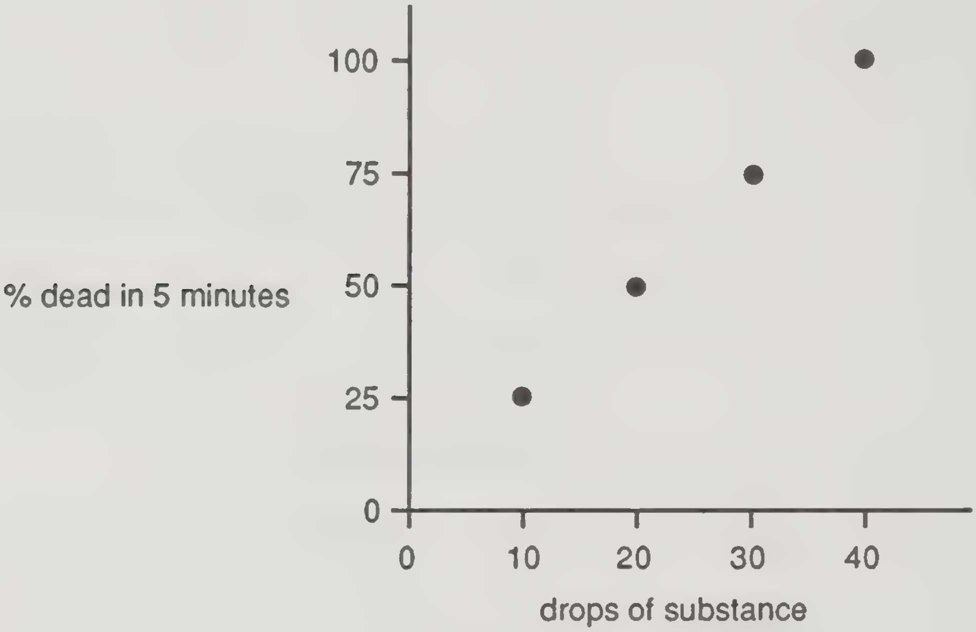
no. drops	no. dead	% dead
0	0	0
3	1	25
6	2	50
9	3	75
12	4	100



8. Chemical insecticide manufacturers are required by law to print information regarding the toxicity of an insecticide on its package label. This information is often expressed as an LD_{50} for mammals. Check pesticide containers at home, at school, or at garden stores and present your findings to the class. Older students can share the task.

EVALUATION

Put the graph shown below on the chalkboard and ask students to answer the following questions in writing.



a. What is the LD_{50} of the substance graphed above?
b. How many drops of this substance would you use if you wanted to kill all of the organisms involved?
c. Can you justify killing 100% of a pest population? If so, explain why. If not, why not?

11.D Resistance to Pesticides

OBJECTIVE	to understand what resistance to pesticides means and how it develops
SKILLS/PROCESSES	application, drawing conclusions, establishing values
VOCABULARY	dose, gene, genetic trait, resist, resistance
MATERIALS	multiple copies of **Spudmashers in a Potato Field** and **Resistant Spudmashers** scissors

PROCEDURE

1. Begin by establishing a definition for resistance. Use suggestions from the class before resorting to the dictionary. Emphasize the ability to withstand or repel disease.

2. Divide the class into groups of three or four students. Distribute a copy of **Spudmashers in a Potato Field** to each group and ask students to cut apart the insects and place them on a desktop or other work area.

3. Develop the following scenario as the class follows the directions.

   > You are potato farmers and your desktop represents a potato field. The insects you have cut out and placed on your desk are spudmashers, and they damage potato plants by eating the leaves. This year spudmashers are doing a lot of damage, and most potato farmers have applied an insecticide called Kill-'em-Dead to their fields. Most of the spudmashers die, and the farmers are pleased. However, a few spudmashers prove resistant to the dose that was used, and they survive (insects with stars).

   At this point students remove all spudmashers that do not have stars. Unstarred spudmashers have been killed by the insecticide. The remaining insects, those with stars, were resistant to the dose of Kill-'em-Dead and survived. At this point, explain that resistance to the insecticide is naturally present in the genes of some spudmashers. Each insect is born either resistant or not resistant to the insecticide. Individuals do not become resistant; however, resistant individuals will pass this genetic trait on to their offspring. Through the survival and reproduction of resistant individuals, resistance builds up in a population.

4. Distribute copies of **Resistant Spudmashers** and ask students to cut apart the insects as they are needed.

   The spudmashers that survived the insecticide now reproduce. For each surviving spudmasher with a single star, students add two single-starred offspring; for each double-starred survivor, they add two double-starred offspring, and so on. The population of spudmashers now consists entirely of resistant individuals, and their numbers will grow larger with each generation.

Soon the spudmashers have again become pests and a threat to the potato crop. What happens if farmers apply the same dose of Kill-'em-Dead that they used earlier? No insects die because the population is entirely made up of resistant insects. What should the farmers do? Suppose they decide to increase the dosage. Spudmashers with only one star are not resistant to the larger dose and they die. Students now remove all single-starred spudmashers from their fields. Insects with more than one star are resistant to the higher dose and survive and continue to reproduce. The spudmasher population grows.

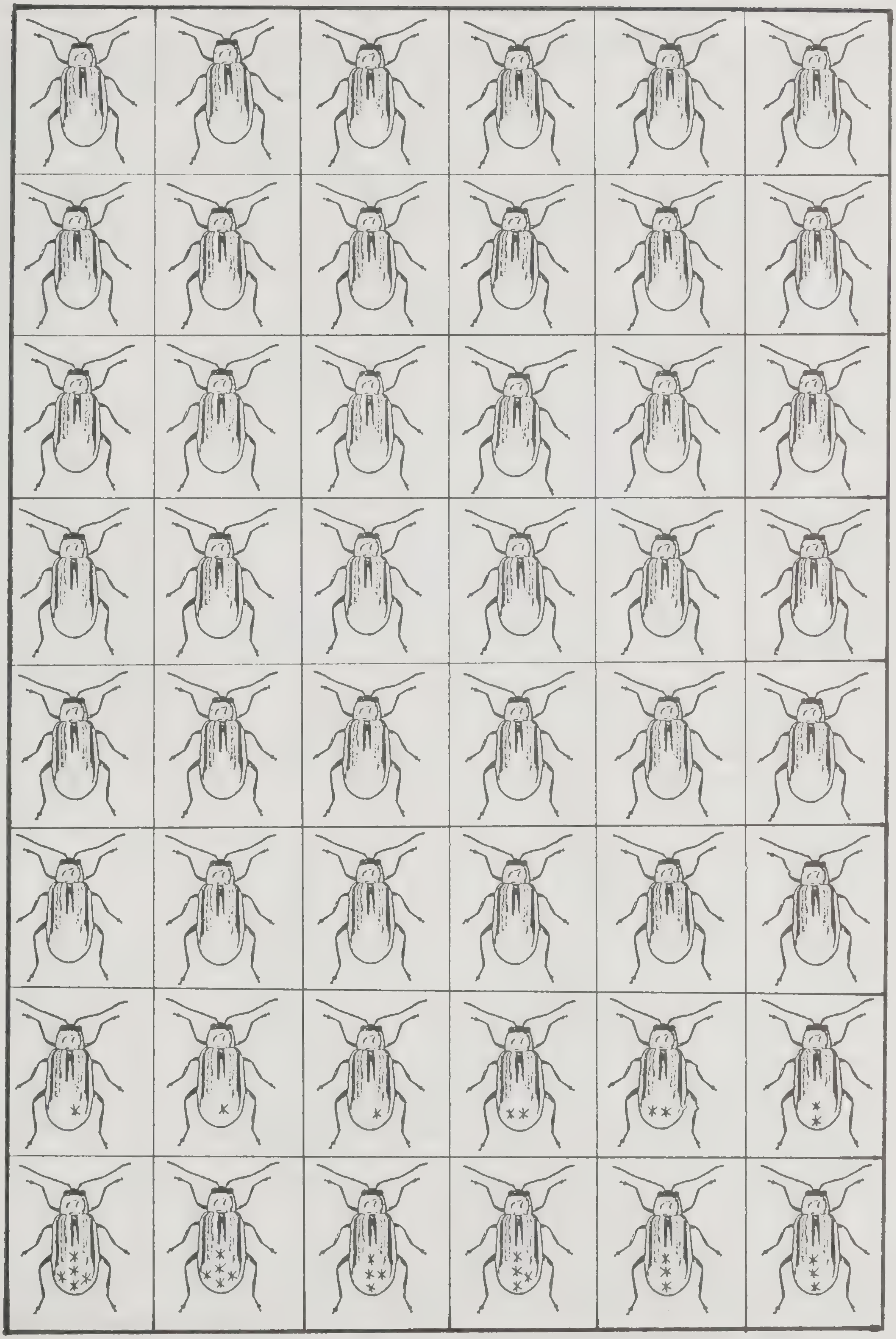
Can farmers spray their fields with an even higher dose of Kill-'em-Dead? Yes, they can but the problem will continue to reoccur. What additional problems must the farmers consider as they continue to increase the dose? List student responses on the board, for example: hazards to human health, damage to other organisms in the environment, introduction of chemicals into the food chain, cost of the insecticide and its application, legal restrictions, ground water contamination.

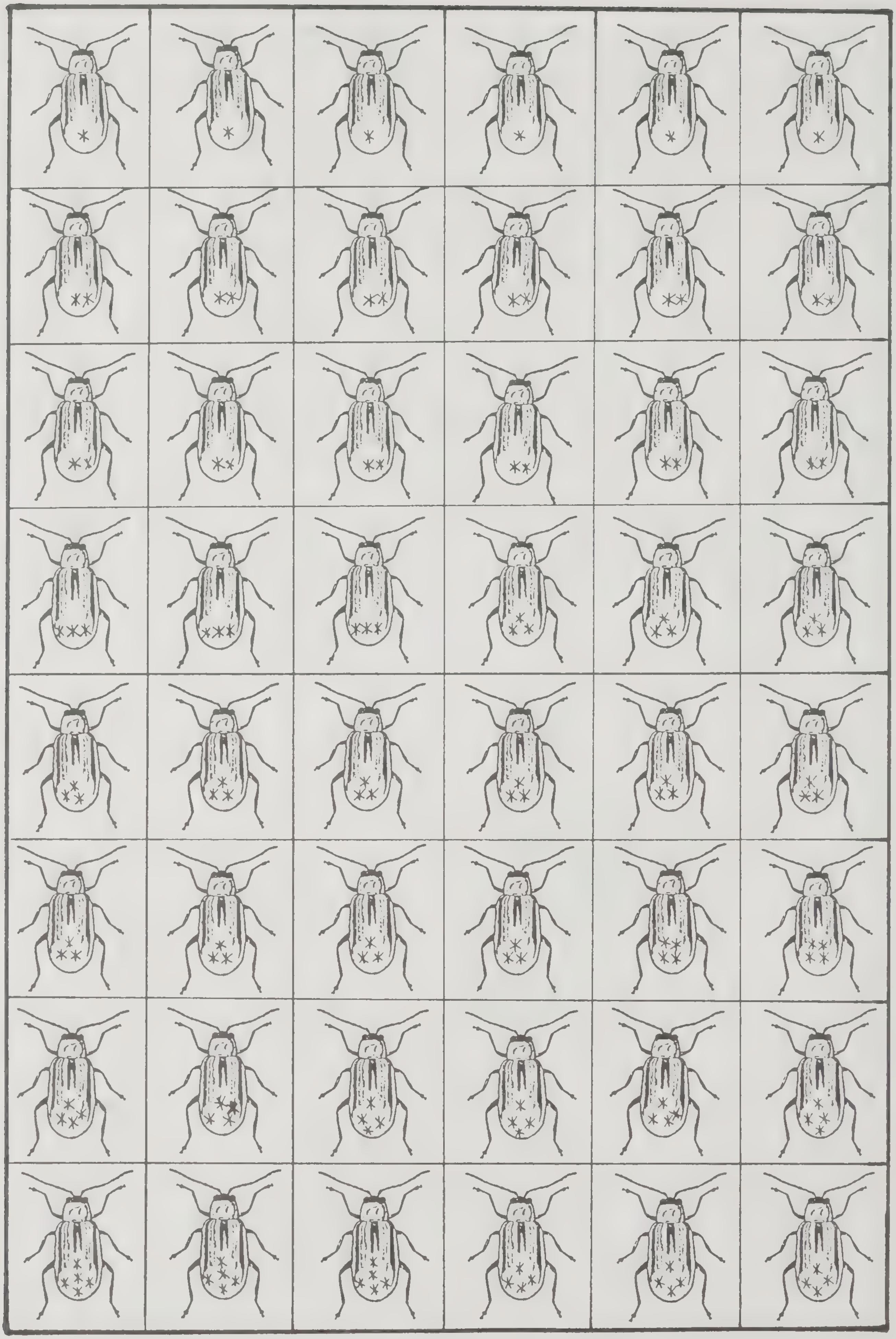
5. Ask each group to devise a definition for insecticide resistance that includes the concepts demonstrated in the scenario. Share these and develop them into a single definition at the chalkboard.

EVALUATION

Insecticides are developed to kill insects; herbicides are designed to kill plants. Plants, like insects, have genes and populations of plants can become resistant to herbicides. Write a brief scenario that describes how a plant can develop resistance to an herbicide. Create a name for the plant and a name for the herbicide.

Spudmashers in a Potato Field





11.E Selectivity of Pesticides

OBJECTIVE	to understand the concept of pesticide selectivity
SKILLS/PROCESSES	application, deduction, identification
VOCABULARY	nontarget organism, selective pesticide, selectivity, systemic pesticide, target pest
MATERIALS	multiple copies of **Pesticide Selectivity 1** and **2**

COMMENTS

How a pesticide is used can determine how selective it is. For example, an agricultural pesticide called aldicarb is extremely toxic to any animal that comes into contact with it—from earthworms to mammals. When aldicarb is properly applied to the soil, however, it comes into contact only with soil-dwelling organisms.

Pesticides may be applied in a number of ways, but the method of application for any given pesticide is governed by law. In this activity, students will consider three methods of applying the same pesticide: aerial spraying, soil application, and baits.

In aerial spraying, the pesticide is sprayed from an airplane or helicopter. Although this method is fairly economical and provides wide coverage, the pesticide will obviously come into contact with many nontarget organisms.

Pesticides can also be applied directly to the soil. In this case, only soil-dwelling animals are affected. If the pesticide is designed to be taken up by the roots of plants, it is called a systemic pesticide and affects only plant-eating organisms.

A very selective method of pesticide application is the use of baits. If the target pest is attracted to certain substances, as twelve-spotted cucumber beetles, for example, are attracted to ground-up squash, then the substance can be laced with pesticide and placed out in the field. Only the attracted insect will eat the bait and die.

A word must be added here regarding persistence and the "migration" of pesticides. The discussion above assumes that when pesticides are properly applied, little or no damage occurs to nontarget organisms. Often this is the case; however, water and biomass are dynamic (constantly moving) within the ecosystem, and if a pesticide persists for any length of time, it may migrate into other areas and affect nontarget organisms. Even if aldicarb, for example, is applied to soil as recommended, a heavy rainfall the following day may wash the pesticide into a river, where it may prove detrimental to the river fauna. Or, as we have seen with DDT, the pesticide can accumulate in organisms higher up in the food chain.

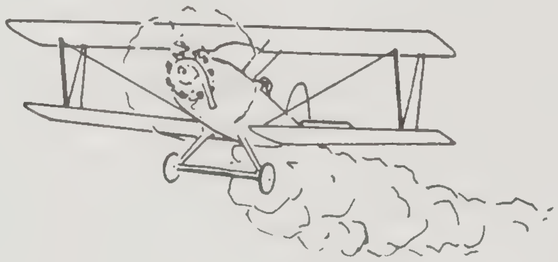
PROCEDURE

1. Review the concept of toxicity introduced in Activity 11.C and introduce the concept of selectivity. Pesticides have a range of selectivity; some may kill only the pest organism, sparing other organisms. Other pesticides adversely affect a wide range of organisms—insects, plants, birds, and mammals. Distribute copies of **Pesticide Selectivity 1** for students to complete. Briefly discuss their responses.

2. Discuss with the class the three methods of application described in the comments above: aerial spraying, soil application, and baits. Be sure that students understand that the way a pesticide is used helps to determine its selectivity. Distribute copies of **Pesticide Selectivity 2** for students to complete. Briefly discuss their answers.

EVALUATION

Ask students to count off in twos. The one's jot down on a slip of paper an instance in which they believe aerial spraying to be the best method of applying a pesticide. They then list justifications for this choice. The two's list as many hazards as they can think of that are associated with the aerial spraying of pesticides. Allow three or four minutes before collecting the slips by number. Appoint a reader for each set of slips. Use the responses from groups one and two as the basis for an informal debate. Encourage discussion about the validity of the information and the values involved.



Pesticide Selectivity 1

Name:

● = toxic to organism

Organism	Pesticide A	Pesticide B	Pesticide C
bluebird	●		
deer	●		
robin	●		
largemouth bass	●	●	
earthworm	●		
raccoon	●		
woodpecker	●		
mushroom			
red fox	●		
honeybee	●	●	
gypsy moth caterpillar	●	●	●
mouse	●		
swallowtail butterfly caterpillar	●	●	●
ladybug	●	●	
bald eagle	●		
oak tree			
rainbow trout	●		
opossum	●		
mosquito	●	●	
dragonfly	●	●	
dog	●		
human	●		

Definition: A selective pesticide kills the pest organism but spares most other organisms, including beneficial or helpful organisms.

Which pesticide above is most selective? ________ least selective? ________

An insecticide is a pesticide that kills mainly insects. Which pesticides above are insecticides? ____

If you wanted to control gypsy moths in your yard, which pesticide would you use? ____

Why? ____

____

Pesticide Selectivity 2

Name:

• = toxic to organism

Name of pesticide: **Eliminator**

Organism	Aerial Spraying	Soil Application	Bait
bluebird	•		
woodpecker	•		
largemouth bass	•		
earthworm	•	•	
raccoon	•		
leaf-eating ant	•	•	•
red fox	•		
gypsy moth caterpillar	•	•	
mouse	•		
swallowtail butterfly caterpillar	•	•	
leaf-eating beetle	•	•	
bald eagle	•		
rainbow trout	•		
soil-dwelling millipede	•	•	
robin	•		
human	•		

The pesticide in the above example is called Eliminator. It is very toxic to all organisms, but it can selectively kill certain organisms if properly applied.

Which of the three ways of applying Eliminator is least selective? ____________________

Which method of application is most selective? ______________________________________

Some pesticides that are applied to soil are absorbed by the roots of plants and spread throughout the leaves and stems. This type of pesticide is called systemic (sis-TEM-ik) because it gets into plant systems. When animals eat such plants, they ingest some of the pesticide. Is Eliminator a systemic pesticide? _______

How do you know? ____

Suppose leaf-eating ants become pests in your field of corn. You learn that these ants are especially attracted to the leaves of radish plants. The label on the bottle of Eliminator notes that you may mix Eliminator with bait to control leaf-eating ants. What kind of bait would you use in your cornfield? ____

Why? ____

11.F Secondary Pests

OBJECTIVE

to understand how insecticides used against a particular pest may cause other insects to increase in numbers and become pests

SKILLS/PROCESSES

application, calculation, identification

VOCABULARY

nonselective insecticide, secondary pests

MATERIALS

multiple copies of **Cast of Characters in the Potato Field** and **Potato Field Worksheet**

COMMENTS

Secondary pests are insects that have become pests as a result of the use of nonselective insecticides to control other pests that were the original target pests. A nonselective insecticide kills all insects with which it comes in contact, including beneficial predators and parasites. Insect species that do not come in contact with the insecticide, of course, survive. For example, insects that live in the soil or insects such as leafrollers and leafminers that live inside of plants often survive the application of an insecticide. If the predators and parasites of these "hidden" species are killed by the insecticide, populations of surviving insects increase in size until they become pests themselves.

To illustate: Following the the widespread use of nonselective insecticides in northeastern Mexico to control the cotton boll weevil, two previously unimportant insects, the cotton bollworm and the tobacco budworm, became major cotton pests. By 1962, these two new pests were of greater economic significance to cotton farmers than the boll weevil had originally been. Similarly, the red-banded leaf roller had rarely been reported as an apple pest in the eastern United States. Following an extensive insecticide spray program to control the codling moth, the red-banded leaf roller became a major apple pest.

PROCEDURE

1. Use the information given above to explain how secondary pests can become major pests through the use of nonselective insecticides. After this brief introduction, distribute copies of **Cast of Characters** and **Potato Field**.

2. Together, read the information about the cast of characters in the potato field. Each student then identifies those insects in his or her potato field and records their numbers in the blanks provided.

3. Student-farmers now apply Kill-'em-Dead to their fields. Kill-'em-Dead is a nonselective insecticide that is sprayed onto potato foliage from an airplane or a tractor. Students cross out all insects killed by that insecticide. Discuss what happened and compare the before and after version of the potato field. What has happened to the number of insect species in the field?

4. Based on what students have learned about the capacity of insects to reproduce (Activity 3.B) and the information given on the

character sheet, they now follow the growth of the spudminer population as described below.

a. Assume that half of the spudminers on each plant are female and that they all lay the maximum number of eggs.

b. Draw the number of spudminers present on each potato leaf the next year; do not count the females and males from the previous year How many spudminers now live in the potato field?

c. Repeat the reproductive cycle two more times (years), always assuming that half of the spudminers on each leaf are female. As before, do not retain the reproducing generation; add only the necessary number of new offspring. How many spudminers are in the field now?

d. Using the information given on the character sheet, determine how many of the potato plants have died. What happened to the population of spudminers when their natural enemies, the zapper and stalker, were eradicated?

EVALUATION

Write a paragraph entitled "The Hidden Cost of Nonselective Insecticides" that documents what you have learned in this activity. Remember, a paragraph develops or illustrates a single main idea.

Cast of Characters in the Potato Field

Spudmasher

This striped beetle feeds on the leaves of the potato plant. Introduced from Europe, it has no natural enemies in the United States. The spudmasher is susceptible to Kill-'em-Dead.

Spudminer

A native insect, this very small larva lives between the top and bottom layers of the potato leaf and leaves a narrow, curving trail visible on the leaf surface as it chews its way through the inside of the leaf. The adult is a tiny black beetle that chews its way out of the potato leaf. Adults live only a very short time and do not eat. Each adult female lays a maximum of 10 eggs between the leaf layers of the potato plant. When a potato leaf has 15 spudminers living in it, the leaf turns yellow and dies; when half of the leaves on a plant are dead, the potato plant itself dies. The spudminer has one predator and one parasite that attack it. It is not susceptible to Kill-'em-Dead because the surface of the leaf protects it from contact with the insecticide.

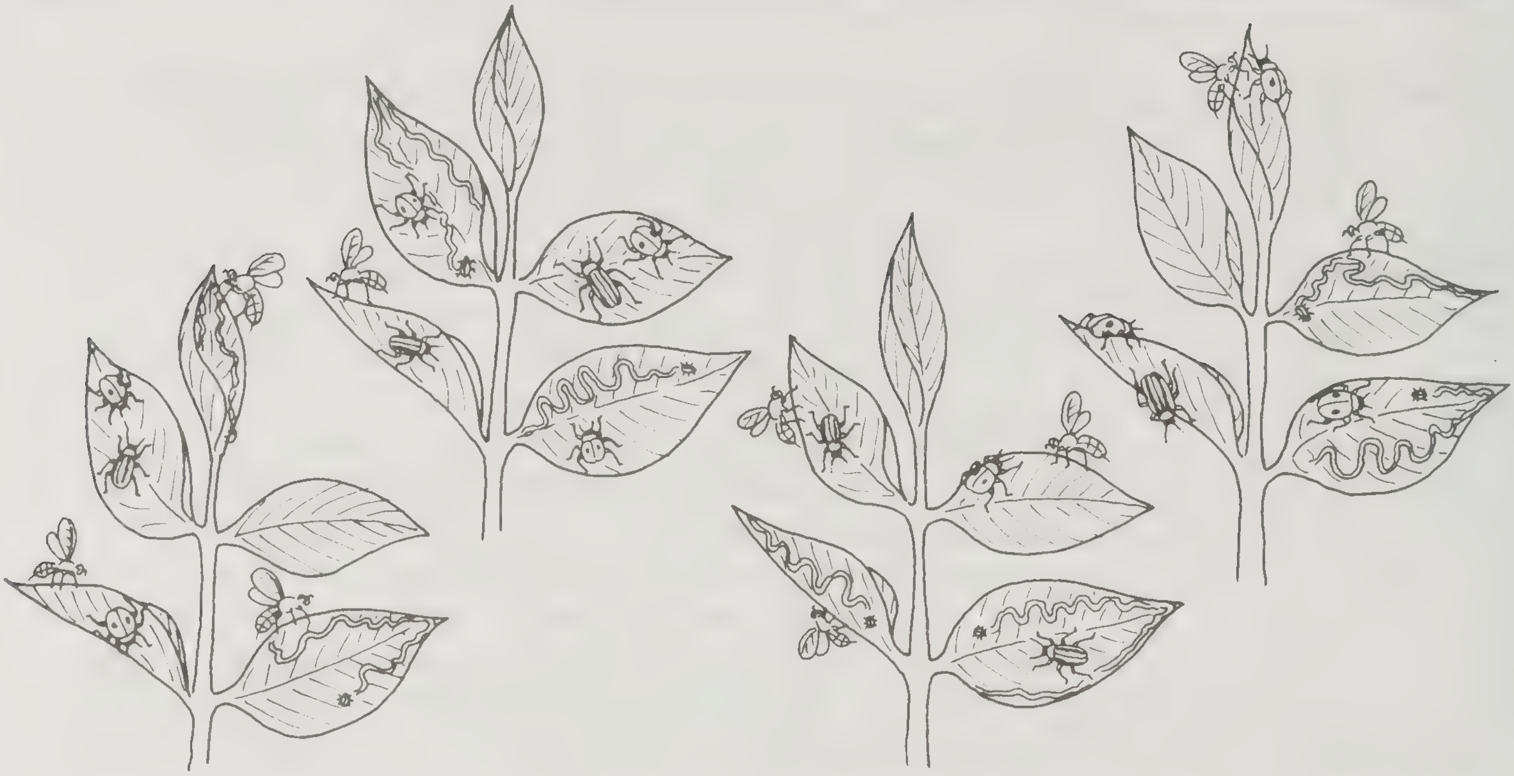
Zapper

The adult zapper is a small, delicate wasp that parasitizes the spudminer. A zapper locates a spudminer by following its trail. When a zapper finds a spudminer, it opens a small hole in the leaf surface and deposits an egg directly into the spudminer. The parasitic larva hatches and grows inside of the spudminer, feeding on the internal juices of the spudminer. Soon the spudminer dies and the zapper larva pupates. When the adult zapper crawls out of its pupa, it makes a hole in the leaf and moves to the outside surface of the leaf, ready to find a mate and more spudminers to parasitize. Zappers are susceptible to Kill-'em-Dead.

Stalker

This small beetle prowls the leaf surface in search of spudminers. When it locates a spudminer trail, it follows it to the spudminer and then uses its sharp mouthparts to rip open the leaf and snatch the spudminer. The stalker is capable of eating many spudminers in a single day. Stalkers are susceptible to Kill-'em-Dead.

Potato Field Worksheet Name:



How many spudminers are there in this potato field? ______________________

How many spudmashers are there in this potato field? ______________________

How many zappers are there in this potato field? ______________________

How many stalkers are there in this potato field? ______________________

11.G The Persistence of Insecticides

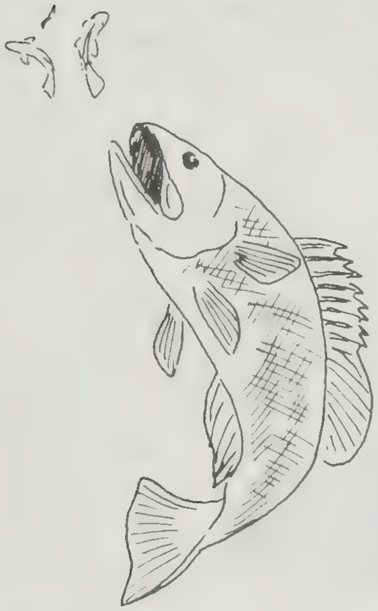
OBJECTIVE to learn about persistence and biological magnification of insecticides

SKILLS/PROCESSES communication, library research, application

VOCABULARY biomagnification, persistence, unit (of measurement)

MATERIALS multiple copies of **Biomagnification of Pesticides 1** and **2**

COMMENTS Insecticides vary widely in their persistence in the environment. Some insecticides are broken down by sunlight, air, or microbes soon after application; others have the ability to persist in the environment or in organisms for much longer periods of time. Depending upon your point of view, persistence can be considered beneficial or detrimental. For example, persistence in the soil may be beneficial to the farmer who will not need to apply the insecticide repeatedly. However, the misuse or overuse of a persistent insecticide can be detrimental to the environment and to organisms that live there.



Biological magnification, commonly called biomagnification, occurs when a chemical accumulates and is present at higher concentrations in organisms that are higher in the food chain. A classic example of the biomagnification of a pesticide occurred with DDT. A highly persistent chemical, DDT can be broken down only by organic solvents. It is not water soluble and therefore cannot be excreted by organisms. DDT, however, is fat soluble and accumulates in the fat cells of animals. Biomagnification of DDT has been found to have serious effects on the reproductive capacities of certain birds of prey (top carnivores) such as peregrine falcons.

PROCEDURE

1. Introduce the concepts of persistence and biomagnification. Briefly explain a **unit**, or given quantity, of pesticide (or any other substance) so students will understand the meaning of the "dots" they will insert on the biomagnification sheet.
2. Distribute **Biomagnification of Pesticides** for students to complete independently. Discuss the exercise when it is finished.

3. Students choose a topic for library research from the list below, which you may elect to alter or expand. When the research is complete, each student reports orally to the class on the findings.
    a. History of DDT in controlling human and animal disease
    b. Laws regarding the banning of DDT as a result of biomagnification
    c. DDT and its effect on peregrine falcons
    d. Reintroduction of peregrine falcons to large cities
    e. Insect resistance to DDT

4. You may wish to schedule time to read selections from Rachel Carson's *Silent Spring* to the class.

EVALUATION

Following the examples on the worksheet or creating their own designs, students devise a backyard food chain that illustrates the biomagnification of a pesticide. Students construct this chain as an assignment for a classmate to complete. Exchange assignments in class, follow instructions, and discuss the completed student-generated assignments.

Biomagnification of Pesticides 1

Name:

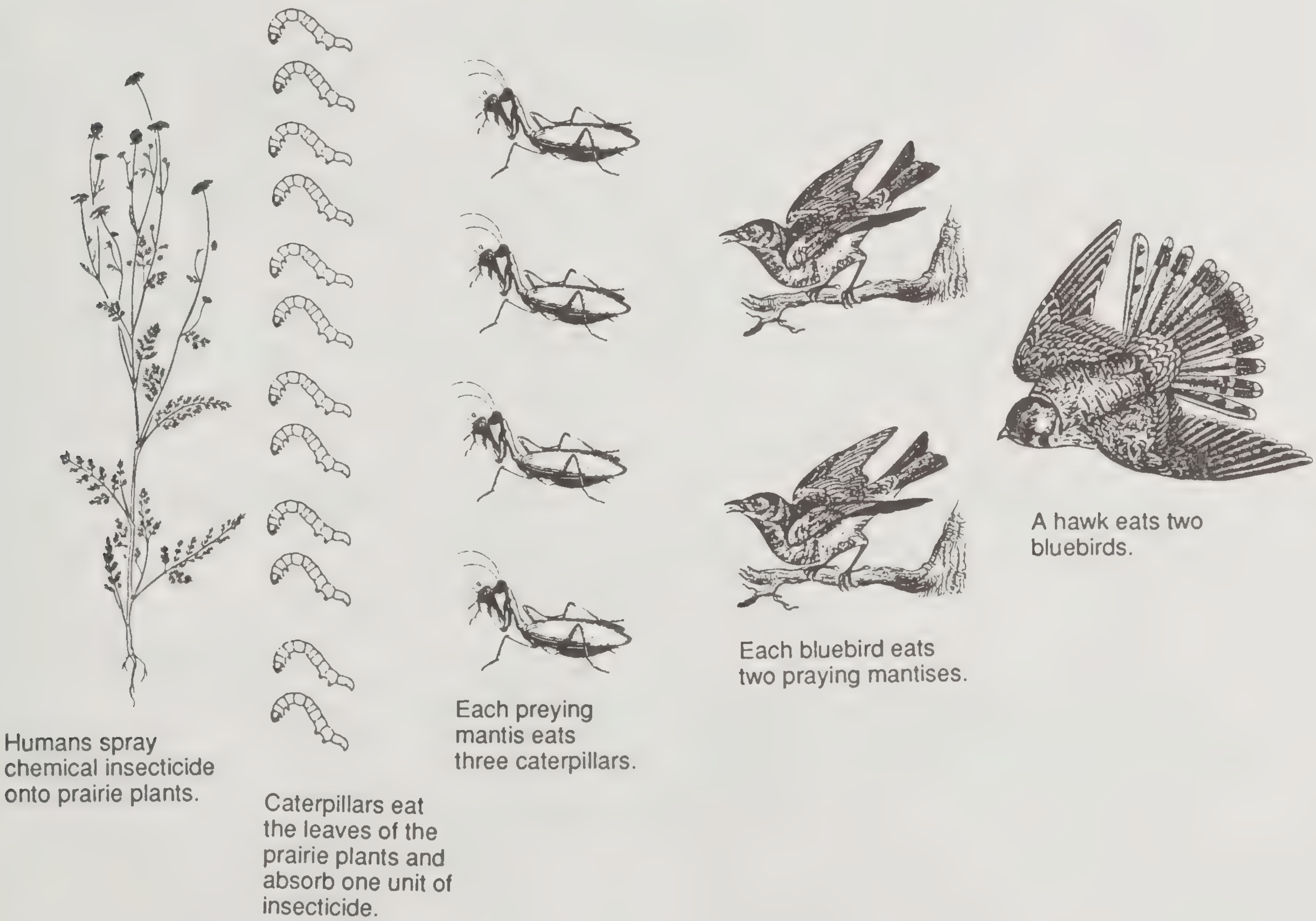
In the prairie community below, the insecticide enters the food chain when the plants on which the caterpillars feed are accidentally sprayed. When the caterpillars feed, they absorb one unit of insecticide. When a praying mantis eats a caterpillar, the insecticide is transferred to the body of the mantis. When a bird eats the mantis, the insecticide in the mantis is transferred to the bird's body. The accumulation of insecticide continues up through the food chain. Follow these instructions for the communities shown below.

1. Draw one small dot in each insect at the "bottom" of the food chain. Each dot represents one unit of insecticide that it has absorbed from the environment.

2. Draw a line from each animal to the animal that eats it.

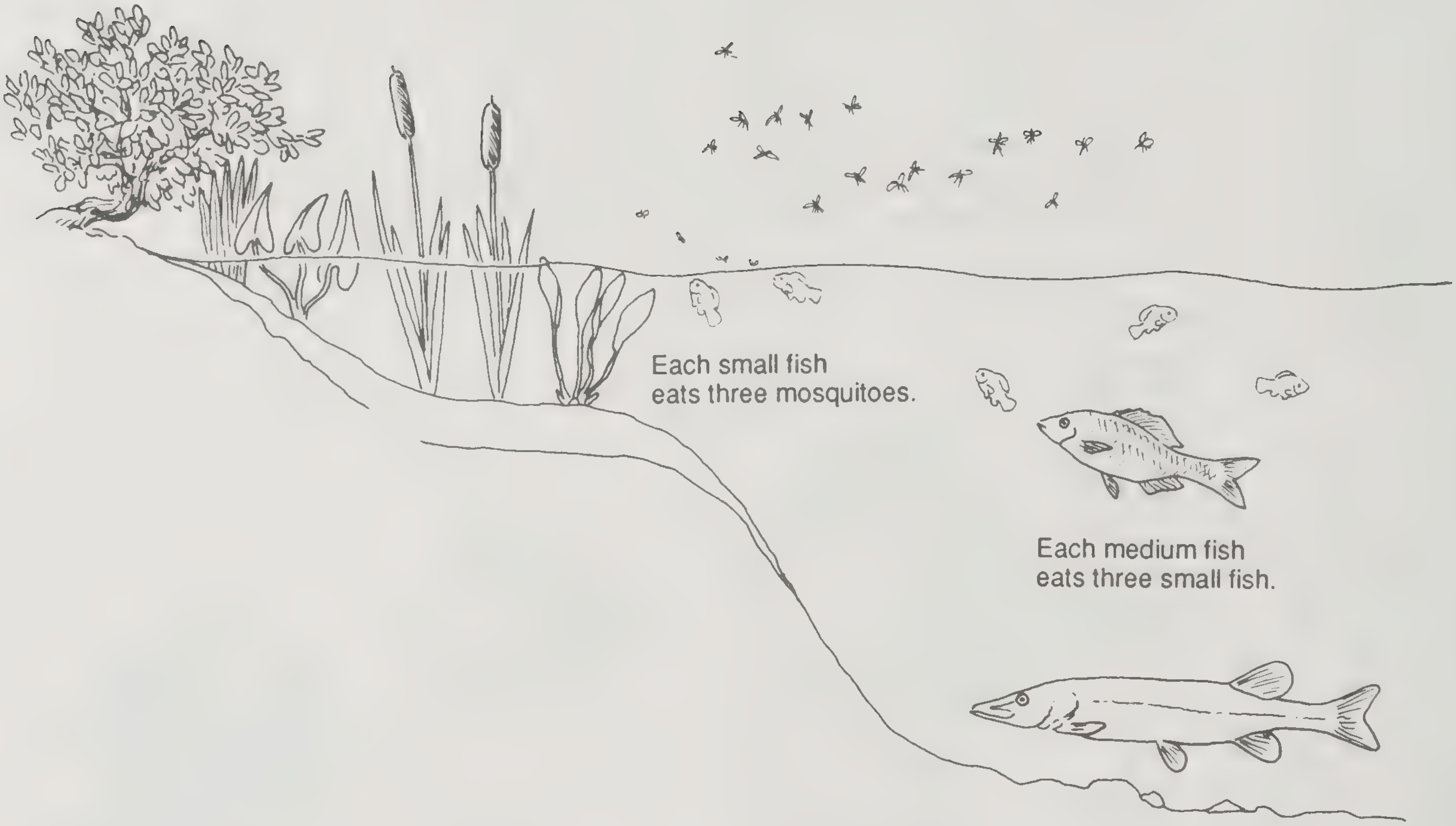
3. Use dots to indicate the units of insecticide that are transferred to each animal. The number of dots increases as the insecticide accumulates in animals higher in the food chain. How would you feel about eating the pike shown in the marsh food web?

Part of a Prairie Food Web


Humans spray chemical insecticide onto prairie plants.
Caterpillars eat the leaves of the prairie plants and absorb one unit of insecticide.
Each preying mantis eats three caterpillars.
Each bluebird eats two praying mantises.
A hawk eats two bluebirds.

Biomagnification of Pesticides 2 Name:

Part of a Marsh Food Web



Humans spray insecticide
to kill adult mosquitoes.

Mosquitoes absorb one unit
of insecticide, die, and fall
into the water.

Each small fish
eats three mosquitoes.

Each medium fish
eats three small fish.

Each large fish
eats two medium fish.

11.H

Bt: An Insecticide Selective for Caterpillars

OBJECTIVE

to learn about *Bacillus thuringiensis* (Bt), a biological insecticide that selectively kills caterpillars

SKILLS /PROCESSES

following precise directions, observation, drawing conclusions, record keeping

VOCABULARY

acidic, alkaline, experimental control, specificity

MATERIALS

kits for rearing caterpillars or caterpillars collected in the wild
crickets or mealworms
babyfood jars with lids that have been punctured
Thuricide®
wide-mouth jar or beaker
eyedroppers
tweezers or forceps
marking pen, tape, labels

COMMENTS

Bt (pronounced "bee-tee") is a commercially produced, natural product of a bacterium (*Bacillus thuringiensis*) that is used as an insecticide. Bt is unusual because it is toxic only to the caterpillars of moths and butterflies. *B. thuringiensis* produces microscopic crystals inside its one-celled body. To produce the insecticide Bt, these crystals are concentrated into liquid or powder form.

Why does Bt kill only caterpillars? When the crystal is exposed to alkaline (basic) conditions, it immediately breaks down into smaller toxic units that are poisonous. Most caterpillars have digestive tracts that are alkaline and soon after they eat the crystals their digestive tracts become paralyzed. They stop feeding and die within a few days. In contrast, the digestive tracts of most animals are acidic and Bt, therefore, is not toxic to them. This specificity to caterpillars makes Bt a very selective insecticide. It may be purchased from garden stores under the trade name Thuricide®.

The hypothesis of this experiment is that Bt kills caterpillars but does not harm crickets or mealworms. You may elect method one, which uses caterpillars obtained from a biological supply house, or method two, which requires students to collect caterpillars outdoors in the spring or fall. The analysis of results is the same for either method.

PROCEDURE

Method One

1. Order kits for rearing caterpillars from a biological supply house. These caterpillars will be reared on an artificial diet according to the directions provided in the kit. Students should participate in the rearing procedure.

2. Begin the experiment after the caterpillars have molted three times. At this time, obtain crickets or mealworms (the larvae of small beetles) from a pet or bait shop. Crickets can be fed dry oatmeal and mealworms will thrive on cornmeal. Be sure to provide water for the crickets in a bottlecap or small container. The number of insects needed varies with the number of set-ups. You may choose to conduct this experiment as a single demonstration for the class or to divide the class into groups, each of which performs the experiment. For each set-up you will need 4 jars for initial feeding, 6 caterpillars, 6 crickets or mealworms, and 12 jars for observation later on. Withhold food from the insects for 3 or 4 hours before beginning the experiment to ensure that the food provided will be eaten.

3. Provide each set-up with 4 jars with punctured lids. These are to be labeled as follows:

jar	treatment	insect	jar label
A	Bt	caterpillar	A/Bt/caterpillar
B	water	caterpillar	B/water/caterpillar
C	Bt	cricket (or mealworm)	C/Bt/cricket (or mealworm)
D	water	cricket (or mealworm)	D/water/cricket (or mealworm)

4. Read the instructions on the Bt label and dilute a quantity in the wide-mouth jar or beaker.

5. Place a chunk (about 1" × 1") of the artificial diet in jar A and jar B. Place one-half teaspoon of oatmeal if crickets are being used or one-half teaspoon of cornmeal if mealworms are being used in jar C and jar D. With a clean eyedroppper, put 10 drops of the Bt solution on the diet chunk in jar A, making certain that the diet is thoroughly coated with the solution. With a second clean eyedropper, place 10 drops of water on the diet chunk in jar B. Using the eyedropper used for jar A, put 10 drops of Bt solution on the oatmeal or cornmeal in jar C, making certain it is thoroughly coated. Using the eyedropper used for jar B, add ten drops of water to the oatmeal or cornmeal in jar D.

6. Jars B and D serve as controls in this experiment. They ensure that the effect that is being measured is caused by the treatment. Here the treatment is Bt and the control is water.

7. Put 3 caterpillars into jar A and 3 into jar B. Put 3 crickets or 3 mealworms into jar C and 3 into jar D. Place the jars in a dimly lit spot and allow the insects to feed for 24 hours.

Method Two

1. Read the procedure for method one because the procedures are essentially the same except for the method of obtaining caterpillars and their diet.

2. Students collect caterpillars for this experiment. Although caterpillars are most readily available in summer, they can be found in spring and fall. Do not use woolly bears in the fall because they will no longer eat. Caterpillars of a single species must be used in the experiment. Good possibilities include the following:

   Cabbage worms: look on cabbage, broccoli, and brussels sprouts for these one-inch-long green caterpillars.

   Fall webworms: look on deciduous trees along roads or at the edges of woods. Wild black cherry is a preferred food. Look for masses of silk webbing at the tips of branches.

   Tomato hornworms: look on tomato plants for these large green caterpillars. Do not collect specimens that have white, fuzzy cocoons attached to them because these have been parasitized and will soon die.

3. Since the insects must be kept alive for at least a few days, a quantity of the caterpillar's food must be collected and stored in a plastic bag in the refrigerator. Always provide fresh foliage. Begin the experiment as soon as possible because keeping fresh food available for caterpillars is a laborious task. The caterpillars should be large enough to be easily observed before beginning the experiment.

4. Prepare the babyfood jars as described in method one with this exception. Instead of the commercial diet for caterpillars, use the leaves stored in the refrigerator. Using a forceps or tweezers, dip a piece of the food plant (about 1.5" × 1.5") into the Bt solution and place it in jar A. Dip a second piece of the same size in water and place it in jar B. Use a clean eye dropper and put 10 drops of the Bt solution on the oatmeal or cornmeal in jar C. Using a clean eyedropper, put 10 drops of water on the oatmeal or cornmeal in jar D. Place 3 caterpillars into jar A and 3 into jar B; place 3 crickets or mealworms into jar C and 3 into jar D. As described in method one, place the jars in a dimly lit spot and allow the insects to feed for 24 hours.

Analysis

1. Whether caterpillars were purchased or collected, the procedure for analysis of results is the same. After 24 hours, remove each insect from the four jars and place it in its own labeled jar. Label the jars A1, A2, A3, B1, B2, etc. You will now have twelve jars with labels: A1-A3, B1-B3, C1-C3, and D1-D3. Continue to provide food as needed for each caterpillar and cricket or mealworm, following the earlier instructions. Continue to provide water for the crickets.

2. Students observe each insect for three days and keep a journal of their observations on individual insects. Control insects should exhibit normal behavior. Students should be alert for such behavioral changes as cessation of feeding, restlessness, inactivity, or death.

3. After three days, discuss the results of the experiment. Did any insects die? Which ones? Based on what you know about Bt combined with the results of the experiment, is the gut of the cricket or the mealworm acidic or basic? What about the gut of the caterpillar?

EVALUATION

Each student concludes his or her journal of observation by writing a summary of results. This journal now serves as the evaluation of the experiment.

11.I Dominoes: An Introduction to Biological Control

OBJECTIVE
to review relationships between organisms in a food web and to introduce the concept of biological control

SKILLS/PROCESSES
application, identification

MATERIALS
domino paper: unlined paper (8 1/2" × 11") cut in half lengthwise (4 1/4" × 11")
black crayons or felt-tip markers

PROCEDURE

1. Ask a student to write on the chalkboard the domino pairs given below with additions of your own. Use this time to review with the class trophic level and food web concepts presented in activities 4.A, 4.B, and 4.C.

2. Distribute two or three domino sheets to each student, who then makes dominoes by folding each sheet in half widthwise (end to end) and tracing along the fold with a black marker. Assign pairs from the list on the board to each student (a few duplicates are acceptable). Students then print one word from each pair on each half of the domino sheet to create dominoes that look like the ones shown below. Ask students to print as large as possible so that the dominoes can be read at a distance. Students may illustrate their dominoes if they wish. If you prefer, prepare the dominoes in advance and substitute lightweight card stock.

3. Tack the starting domino (deer/rabbit) on the bulletin board or place it on the floor. The game is played by volunteers adding one domino at a time so that the organism on one half of a domino feeds upon or is fed upon by the organism on the domino it touches. As each student adds a domino, he or she explains why that play is justified. Encourage students to use terms like these: predator, parasite, disease, prey, host, herbivore, carnivore, and natural enemy. The first three words, predator, parasite, and disease, are used regularly in activities in Section 11 and 12 and are important in discussing the biological control of insects. Predators, parasites, and diseases are natural enemies of the organisms they eat.

4. As students add dominoes, the community of organisms illustrated by the game becomes more complex. Continue play until each student has added at least one domino or until as many dominoes as possible have been played.

5. After the game has finished but before the dominoes are disturbed, select an herbivore that is in play and ask the class to assume that it has become a pest. Which organisms in play are potential natural enemies of this pest? If we want to control the pest, which organisms might we consider as biological control organisms?

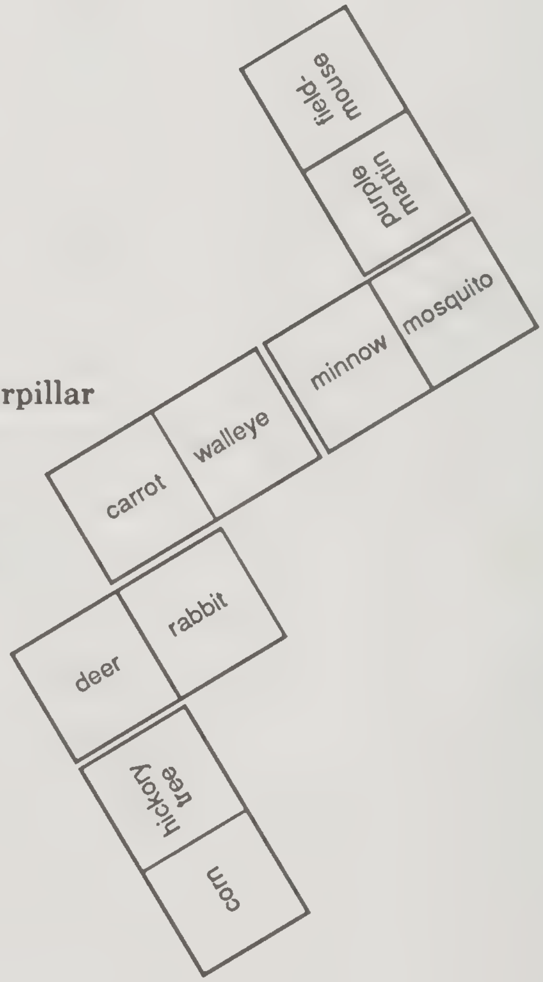
6. Discuss how the numbers of a given predator, parasite, or disease organism affect the numbers of the organism consumed. This relationship is the basis for the biological control of pests. Develop with the class a working definition of biological control, emphasizing that it involves the use of natural enemies by humans to help control pests. Through biological control, we increase the numbers of a pest's natural enemies so that the pest's numbers decrease. If your class played the population dynamics game (Activity 8.E), a reminder of the conclusions reached there will be helpful: the numbers of prey affect the numbers of predators and vice versa. By managing the numbers of natural enemies, we influence the numbers of prey (pests).

EVALUATION

Students sketch five dominoes in play, using the pairs listed on the chalkboard or providing pairs of their own. They then write a paragraph to accompany this illustration in which they explain the relationships among the animals in the food web they have created.

Domino Pairs

deer/rabbit
alfalfa/grass
apple tree/aphid
preying mantis/oak tree
crayfish/largemouth bass
algae/cattail
oak tree/red fox
coyote/fly
mosquito/grasshopper
cow/wildflower
tick/honeybee
flea/swallowtail butterfly caterpillar
dragonfly/aphid
grasshopper/ladybug
grass/gypsy moth caterpillar
milkweed plant/pussy willow
wild rose/daisy
hickory tree/corn
elm tree/raccoon
wolf/oppossum
walleye/carrot
pike/ants
minnow/mosquito
water beetle/minnow
mushroom/deer
fieldmouse/flycatcher
bat/grackle
frog/owl
etc.



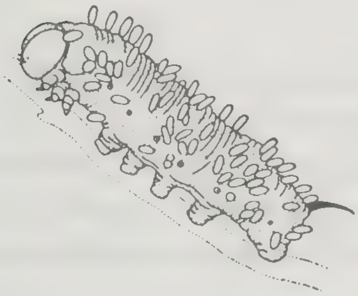
11.J Biological Control: Importation

OBJECTIVE: to learn how scientists choose natural enemies to control introduced pests

SKILLS/PROCESSES: application, data analysis, inference, making value judgments

MATERIALS: multiple copies of **Rules for Selecting Biological Control Organisms** and **Biological Control Organisms, Sets A, B,** and **C.**

PROCEDURE



1. Review the concept of biological control, reemphasizing that such natural enemies as predators, parasites, and diseases are used to help control pests. Explain that pests have often been introduced; that is, they are exotic species. (Remind students of what happened when Trouvelot introduced the gypsy moth to Massachusetts.) If a pest is an introduced species, predators, parasites, and diseases from its native home are possibile for use as biological control organisms. These potential controls must, however, be studied with great care before they are introduced into the area now occupied by the nonnative pest.

2. Distribute copies of **Rules for Selecting Biological Control Organisms** and read and discuss them together.

3. Develop the following scenario:

    > Gypsy moths are eating all the leaves from the trees in our state. You are an entomologist. The United States Department of Agriculture decides to send you to various parts of Europe, Asia, and North Africa (native homes of the gypsy moth) to study natural enemies of the gypsy moth.

4. Ask students to count off by threes. Give the one's copies of **Biological Control Organisms Set A**; give the two's copies of **Set B** and the three's copies of **Set C**.

5. Each student-entomologist reads this material, thereby "discovering" three natural enemies of the gypsy moth: a predator, a parasite, and a disease. Referring back to the four rules for selecting a biological control, each student decides which of the three organisms he or she will recommend to the USDA for importation into the United States as a biological control of the gypsy moth. Tally the choices for each set (A, B, and C) on the chalkboard. For each set, one organism is the wisest choice: Predator A, Parasite B, and Disease C. If students make other choices, ask for justification.

EVALUATION: Students list at least one reason why they did not recommend the importation of the other two organisms in the set assigned to them.

Rules for Selecting Biological Control Organisms

Four rules applied by entomologists when selecting organisms to be used as biological controls are listed below.

1. To be effective, an introduced biological control organism must prey only (or mostly) on the target pest.

    A pest is often an organism from another country that has become a pest because it was imported without its natural enemies. These natural enemies helped control the pest in its native home and should show promise for controlling the pest in its new home.

2. The imported biological control organism must come from a climate and biological community similar to those found in the area to which it will be introduced.

    For example, if you want to control gypsy moths in Canadian forests, a biological control organism that can withstand Canada's cold climate must be chosen. The imported organism must be able to survive and reproduce in its new environment.

3. An organism used for biological control must be easy to capture or raise in large numbers.

    If a program of biological control is to succeed, thousands of individuals of a particular natural enemy must be released into the environment; that effort may require several years. Large-scale releases are the best way to assure that enough males and females find each other, mate, and reproduce in their new home. Scientists, therefore, must be able to find inexpensive ways to capture the biological control organism or raise it in captivity.

4. A biological control organism must have little or no effect on organisms in the new environment other than the target pest. Further, the control organism must not itself become a pest.

    Any species must be carefully studied before it is introduced into an area to which it is not native.

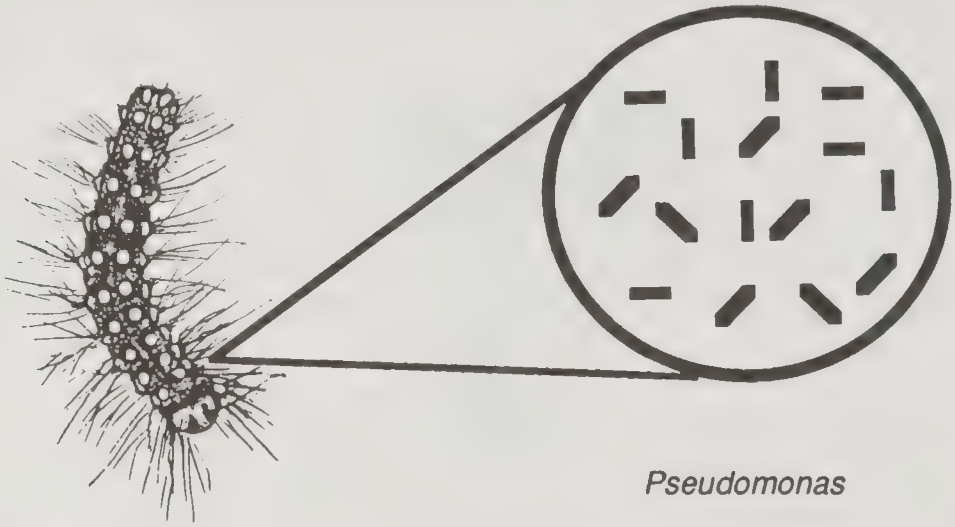
Calosoma sycophanta eating a gypsy moth caterpillar

You first discovered this beetle in the forests of Poland. It was eating a gypsy moth caterpillar on the trunk of a tree. The beetle's strong jaws easily pierced the caterpillar's skin and it ate the caterpillars internal organs. You have since discovered that this beetle also eats gypsy moth pupae and even adult gypsy moths.

You check Polish insect identification books and find that this beetle's scientific name is *Calosoma sycophanta* (kal-uh-SO-muh sy-ko-FAN-tah). It is commonly called the fiery caterpillar hunter. Local entomologists at Warsaw University provide you the following information about *C. sycophanta.*

This beetle can be found in any European forest where gypsy moths occur. Its lifestyle is adapted for eating gypsy moths. It hibernates in the ground during the cold winter months and emerges in spring when gypsy moth caterpillars are beginning to grow. Each beetle lives for several years. One female beetle may lay up to 50 eggs each spring, or even more when there is an abundance of gypsy moth caterpillars.

Fiery caterpillar hunters climb trees in search of prey. They are easy to collect alive in traps placed on trees or in the ground.



Pseudomonas

In Portugal, after a heavy rainstorm, you collect several hundred gypsy moth larvae and bring them back to the Forestry Institute to look for parasites. All the larvae die of no apparent cause within a few days. Upon examination under the microscope, you find that each caterpillar is filled with a type of bacteria. Could this be a disease of gypsy moths with the potential for release in the U.S.?

As a first step, a bacteriologist at the Portuguese Forestry Institute identifies the bacteria as a species of *Pseudomonas* (soo-doe-MOAN-az) and says that it is a common inhabitant of the guts of caterpillars. To determine if *Pseudomonas* causes a disease in gypsy moths, you feed it to several gypsy moth caterpillars. Nothing happens to them. Why did the caterpillars collected seem to be infected with *Pseudomonas*? Upon reading about this bacterium, you find that it causes disease only in caterpillars that have been injured or stressed in some way. You conclude that the caterpillars collected after the rainstorm had been injured, which allowed the *Pseudomonas* bacterium to become pathogenic (disease causing).

Biological Control Organisms Set A: Parasite

Compsilura concinnata

In France, you collect 100 gypsy moth caterpillars, take them to the laboratory, and place them in separate jars with food. You check them every day and discover that one of the jars now also contains a fly puparium from which a fly soon emerges. The caterpillar in the jar is dead.

You take the fly to a French entomologist. She identifies it as the parasite *Compsilura concinnata* (komp-si-LURE-uh kon-sin-NAY-tuh). It has no common name. This fly is a member of the insect order Diptera. One of your gypsy moth caterpillars was a host for this parasitic fly. An entomology book describes the life cycle of this parasitic fly as follows.

The female parasitic fly deposits a young fly larva (not an egg) on the skin of a host caterpillar. The young fly larva chews through the skin of the caterpillar and begins to eat its internal organs. The fly larva grows larger, crawls out of the host, and pupates. About a week later an adult fly emerges from the puparium. Meanwhile, the host caterpillar has stopped eating and eventually dies.

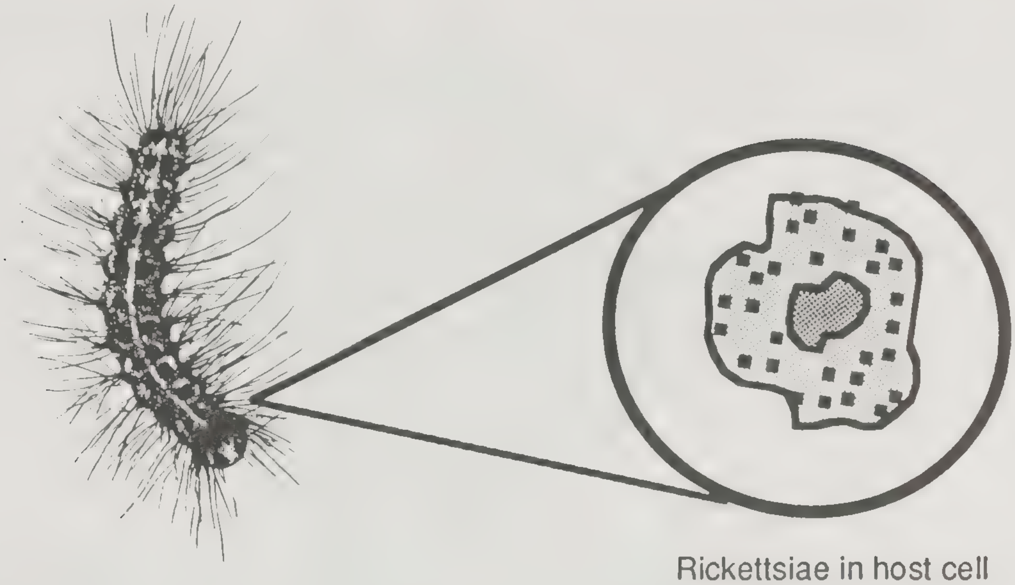
Compsilura concinnata is not often found in gypsy moths and cannot survive the winter inside gypsy moth hosts. This fly is a parasite of more than 160 different species of insects.

Akis bacarozzo

You are collecting insects in a forest in Yugoslavia. On a tree trunk you see a large brownish-black beetle eating the eggs in a gypsy moth egg mass. You collect the insect and return to the laboratory. A Yugoslavian entomologist identifies this beetle as *Akis bacarozzo* (AY-kiss buh-KARE-oh-zoe), or the darkling beetle. It belongs to the insect order Coleoptera.

Yugoslavian entomologists and European insect books supply you with more information about the darkling beetle. This beetle not only eats an occasional gypsy moth egg, but it also feeds on stored grain such as wheat, corn, and rice. In fact, the darkling beetle eats hundreds of different foods.

In Yugoslavia, *Akis bacarozzo* is often a pest in grain storage areas such as grain elevators.



Rickettsiae in host cell

You collect sick-looking gypsy moth caterpillars in Switzerland and bring them to the laboratory you are visiting at Geneva University. You dissect some of them to discover what is wrong, but you see no disease organisms in them with a regular microscope. You send some of the sick caterpillars to a scientist in Sweden, who dissects them and looks at the internal organs with a very powerful microscope called an electron microscope.

This microscope magnifies 50,000 times and enables the Swedish scientist to see the cause of the caterpillars' sickness. He mails the photographs he took through the electron microscope to you at Geneva University.

You show the photographs to other scientists in Switzerland, and one of them identifies the organism as rickettsia (rick-KETT-see-uh). The plural of rickettsia is rickettsiae (rick-KETT-see-ee). Rickettsiae are like bacteria but even smaller. The scientist tells you that rickettsiae are known to cause several human illnesses, such as Rocky Mountain Spotted Fever. In fact, many of the scientists at Geneva University agree that it might be dangerous to study this rickettsia in the laboratory unless specific precautions are taken because we do not know whether insect rickettsiae are contagious to humans.

Cotesia melanoscelus

This tiny wasp is less than 1/8" long. Its scientific name is *Cotesia melanoscelus* (KOTE-see-uh mel-an-oh-SELL-us). Primarily a parasite of gypsy moth caterpillars, it is found in European forests and spends the winter as a pupa.

The female parasitic wasp lays its egg under the skin of the gypsy moth caterpillar. The egg hatches and the young wasp larva eats the internal organs of the caterpillar. Meanwhile, the caterpillar stops eating and eventually dies. When it is fully grown, the wasp larva comes out of the caterpillar, spins a white cocoon, and becomes a pupa. In about a week, the adult wasp emerges and flies away to mate and lay eggs in other gypsy moth caterpillars. A female wasp can parasitize as many as 200 gypsy moth caterpillars.

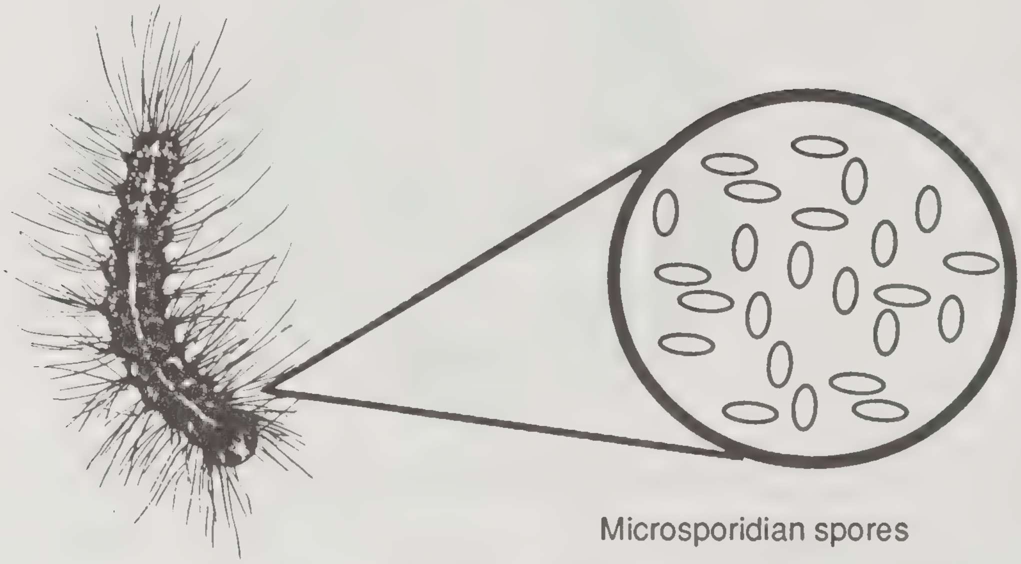
This wasp is easily collected from wild European gypsy moths by scientists, who keep them alive in captivity by feeding honey to the adults. Gypsy moth caterpillars are provided so that the wasps have egg-laying sites and a place in which the wasp larvae may grow.

European dormouse eating a gypsy moth pupa

The European dormouse is a mammal. Its scientific name is *Dyromys nitedula* (die-ROME-is ny-TED-yu-la). It lives in the forested areas over much of Europe and eats a wide variety of foods such as insects, grain, nuts, and berries. Although dormice will eat gypsy moth pupae, they do not like to eat the hairy caterpillars.

Dormice are similar to the native North American white-footed mouse, *Peromyscus leucopus* (pear-oh-MISS-kus loo-KO-pus). They eat similar foods and live in similar habitats. If imported, dormice might compete with the native white-footed mouse for food and habitat.

Biological Control Organisms Set C: Disease



Microsporidian spores

You are in a forest in Germany and spot some sick-looking gypsy moth caterpillars. You collect them and take them back to the laboratory, where you dissect them and look at their internal organs through a microscope. You see little oval organisms through the microscope, and you suspect this may be the disease that made the caterpillars sick. You don't know what these little oval organisms are and ask scientists at Berlin University to identify them. One scientist tells you that your disease organism is a microsporidium (MIKE-row-spore-ID-dee-um). You find a book on microsporidia (plural of microsporidium) and read the following information.

Microsporidia are common diseases of insects. There are thousands of species of microsporidia in the world. Certain species usually infect only one species of insect. For example, a species of microsporidium found in ladybugs is probably not infectious to other species of insects. In other words, many microsporidia have adapted to live inside a single insect species and do not do well inside other insects.

Microsporidia can be placed on the surface of food to be eaten by a gypsy moth caterpillar. When the caterpillar eats the food it becomes infected. The microsporidia then multiply inside the caterpillar. The caterpillar can later be dissected and the microsporidia collected. Microsporidia, therefore, are easy to raise in the laboratory.

Gypsy moth microsporidia survive inside gypsy moth eggs during the winter.

Apanteles lacteicolor

The scientific name of this tiny wasp is *Apanteles lacteicolor* (uh-PAN-tuh-leez LACK-tee-i-color). The adult wasp is only 1/8" long. It was discovered in Morocco.

Although this wasp is mainly a parasite of browntail moth caterpillars, it occasionally parasitizes gypsy moth caterpillars. It can survive only where large numbers of browntail moths occur because it overwinters only in the browntail moth.

To raise this parasitic wasp in captivity, scientists must provide browntail moth caterpillars as egg-laying sites for the wasps.

11.K Mechanical Control: Searching for Egg Masses

OBJECTIVE

to learn a mechanical method used to control gypsy moths

SKILLS/PROCESSES

inference, observation, record keeping, calculations

MATERIALS

light brown construction paper or large grocery sacks
scissors and cellophane tape

COMMENTS

Cultural, mechanical, or physical control methods are often used in conjunction with chemical or biological control programs.

Cultural control is the use of agricultural practices to reduce insect populations. The most famous example is the cultural control of the Hessian fly—a pest of wheat. The program includes delayed fall planting of wheat to escape the egg-laying period of female Hessian flies, the planting of fly-resistant varieties of wheat, and the removal of plant debris from wheat fields after harvest. These farming practices have greatly decreased the impact of the Hessian fly on wheat in the United States.

Mechanical control relies on devices that affect the pest directly or radically alter its physical environment. Examples include hand picking insects from garden crops or trapping insects with sticky bands or pheromone traps.

Physical controls may use electricity, sound waves, temperature extremes, or light to kill insects or to attract them to killing mechanisms. An example is the popular "bug-zapper," which uses light to attract and electricity to kill insects. Extremely high or low temperatures are often used to control pests in grain stored in elevators.

PROCEDURE

1. Use an oval pattern to cut 30 gypsy moth egg masses from the construction paper. Number these from 1 through 30. Just prior to the activity, choose an area of the school grounds to serve as the focal point of a gypsy moth infestation. Secure with cellophane tape most of the 30 egg masses near this focal point. Hiding places include downspouts, bricks of the school building, playground equipment, and trunks or lower branches of trees.

2. Explain to the class that collecting egg masses is a simple mechanical method used to control gypsy moths. Collecting is done by trained personnel who search for egg masses. When a mass is found, the collector scrapes it from the surface and places it in a container. At the end of the collection period, kerosene is added to the container and the egg masses are burned.

3. Develop the following scenario:

   Students are USDA or city employees. Their job is to find and collect egg masses in the school yard. Allow 5–10 minutes for the search. Record the time taken for the search.

4. Return to the classroom and count the egg masses collected. How many masses remain in the school yard? What percentage were found? If each egg mass averages 500 eggs, how many gypsy moth caterpillars could hatch next spring in the school yard? Is collection an effective method of controlling the gypsy moth?

5. Determine the collective time spent locating egg masses: number of students × length of search. If labor is $10.00 an hour, how much did the collection cost? If an infested area was 100 times as large as the school yard and the same concentration per unit area was applied, how long would the search take? How much would labor cost? How many egg masses would be missed if the same success ratio applied?

   Example:
   17 of 30 egg masses found = 13 egg masses missing
   100 - (13/30 × 100) = 56.7% egg masses found
   13 egg masses × 500 eggs = 6500 possible gypsy moth caterpillars

   25 students × 10 minutes time = 250 minutes or 4 hours 15 minutes collection time

   At $10.00 per hour, collection costs = $42.50

   100 × 30 egg masses per unit of area = 3000 possible egg masses

   100 × 250 minutes = 25000 minutes or 416.7 hours or 52 8-hour work days

   417 hours × $10.00 per hour = $4170.00

   56.7% × 3000 egg masses = 1701 egg masses found; 1299 egg masses remaining

   1299 egg masses × 500 eggs per mass = 649,500 possible gypsy moth caterpillars the following year

6. List on the chalkboard problems associated with collecting egg masses as a control method for the gypsy moth: overlooked egg masses, time-consuming method, labor-intensive method, high cost. Discuss the advantages and disadvantages of other mechanical methods of controlling the gypsy moth: pheromone traps, no-pest strips, swatting or squashing.

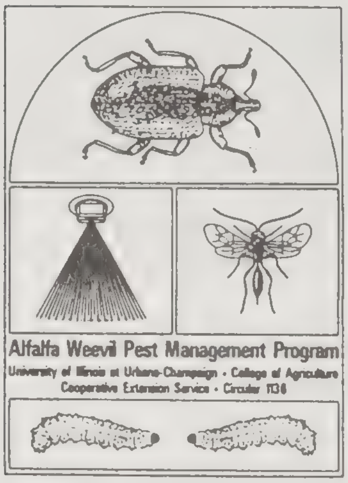
7. Introduce the other methods of pest control noted above: cultural and physical controls. What are their advantages and disadvantages?

EVALUATION

Students list the four types of controls to which they have now been introduced and two examples of each type.

12.

Integrated Pest Management: Background Information


Alfalfa Weevil Pest Management Program
University of Illinois at Urbana-Champaign • College of Agriculture
Cooperative Extension Service • Circular 1136

The term Integrated Pest Management (IPM) identifies a practical approach to pest control that incorporates the three most commonly used methods of insect control—chemical insecticides, biological control, and cultural control—into a comprehensive management plan. The goal of IPM is not to eliminate a pest completely but to reduce its numbers to the point where the pest no longer causes economic damage.

What is economic damage? It occurs when a pest causes damage directly to a "salable" product. Consider, for example, the corn earworm. Most sweet corn shoppers return ears to the bin if they see indication of insects. Another way pests cause economic damage is to affect the productivity of a plant so that it is unable to produce fruit or seed or produces a markedly decreased yield. An example is the squash borer, a common garden pest. This insect bores a hole into the stem of a squash plant, thereby allowing the introduction of bacteria and disease organisms that can kill the plant. This damage is reflected in a monetary loss to the producer. IPM uses current control tools to keep pest numbers below the level of economic hardship. This economic-injury level varies among crops and among the various insect pests that attack a particular crop.

An integrated pest management program is an intricate juggling act of control tactics, knowledge of the pest species involved, and timing. All of the control methods used must be compatible with one another. If an IPM program utilizes a chemical insecticide and a parasitic wasp, the timing of the application must not interfere with the life cycle of the wasp. An IPM program requires careful monitoring and frequent reassessment.

Often IPM provides a more economical way of controlling an insect pest than do conventional spray programs. The environmental impact of an IPM program is also less because it does not rely heavily on chemical products. Because IPM programs cost less and because they have fewer negative impacts on the environment, they will be used more frequently in the future and for a wider range of crops.

12.A Making Decisions

OBJECTIVE	to learn alternative methods of gypsy moth control and how to make the best choice among those alternatives
SKILLS/PROCESSES	evaluation, decision making, application
VOCABULARY	Integrated Pest Management (IPM)
MATERIALS	a single copy of **Definition Cards** and a single copy of each set of **Information Cards 1–5** thumbtacks
COMMENTS	Because this activity is long, the procedure has been scheduled for three class periods.

PROCEDURE

Day One

1. Prepare a bulletin board with the headings "Positive" on the left and "Negative" on the right. Make five side headings as shown below.

	Positive	Negative
1. chemical insecticide		
2. mass pheromone trapping		
3. Bt		
4. egg mass collection		
5. no action		

2. Cut apart the **Definition Cards**, one for each of the five control options you have used as side headings on the bulletin board; retain these cards for yourself. Cut apart the five sets of information cards; give at least one card to each student.

3. Read from the bulletin board the first option for controlling gypsy moths: chemical insecticide. Then read the corresponding definition card and tack that card to the left of the first side heading on the bulletin board. Ask a student holding a chemical insecticide card to read the information on that card to the class. Decide as a group whether the student should tack that card in the positive or negative column. Repeat until all the information cards for chemical insecticides are in place on the bulletin board.

4. Repeat Step 3 for each of the remaining four control options. Encourage as much discussion as possible.

5. When all the information cards are in place, decide as a class which control option should be used in their community. Attach a symbol to designate that option on the bulletin board. Caution students that the quantity of negative or positive cards for a given control option may not be the best approach to a decision. What

about differences in level or magnitude of impact? What about economic realities? Students must decide, for example, if preventing harm to other organisms in their environment is worth the cost of pheromone trapping.

6. Keep the cards in place on the bulletin board for the following day's activity.

Day Two

1. Assign one of the following roles to each student. Add others of your own devising and incorporate suggestions from the class.

backpacker
forester
beekeeper
fisherman
construction worker
president of a pesticide company
homemaker with two small children
owner of a summer camp for children
science teacher
ecologist
tree-nursery owner
unemployed person
mayor
chemical manufacturer
owner of a logging company
homeowner
environmentalist
real-estate agent

2. In their new roles, ask students to vote for or against each control option gone over in class the preceding day. Ask for justification for these decisions, and encourage students to use the information on the bulletin board. Discuss why people voted the way they did. What kinds of interest and information governed decisions? Do individuals interpret the same information in different ways?

Day Three

1. Remind students that on the two preceding days they have looked at the advantages and disadvantages of five options for controlling the gypsy moth. They have also discovered how self-interest and motive may affect the interpretation of information. Today the same five options will be considered, but a new idea will be introduced: combining one or more options as a single control strategy.

   A realistic example of combining two options for controlling the gypsy moth control is found in the program currently used in Illinois. When gypsy moths are found in new areas of the state, the Illinois Department of Agriculture recommends two sprayings of Bt in the spring followed by the mass pheromone trapping of males in late summer when the adults emerge.

   The combination of two or more control options is called Integrated Pest Management. Under Integrated Pest Management, types of insecticides, times of application, use of beneficial organisms, and use of such cultural controls as pheromone trapping are planned so that minimum impact is made on the environment and experienced by nontarget organisms, including those that are natural enemies of the pest.

2. Ask the class to choose two control options to use in their community. Discuss the pros and cons before the final vote. Explain that the class has just formulated an Integrated Pest Management Program for their community. How does that

program comply with the definition of Integrated Pest Management given above?

EVALUATION

Ask students to think of similar examples where a variety of tactics are used to control a certain problem. A good example is treating the common cold with rest, plenty of liquids, and aspirin. Is this a form of Integrated Pest Management?

CHEMICAL INSECTICIDES

Chemical insecticides are natural or artificial products used to kill insects.

MASS PHEROMONE TRAPPING

Pheromone traps are small triangle-shaped boxes with openings at both ends. Each trap is lined with a sticky coating and contains a small amount of artificial pheromone (scent) to attract male gypsy moths. When a male enters the trap, it sticks to the interior and soon dies. In mass pheromone trapping, one trap is placed approximately every 40 feet. Ideally, all male moths in the area will be caught before they have a chance to mate with females.

BACILLUS THURINGIENSIS (Bt)

Bt is a biological insecticide derived from a bacterium called *Bacillus thuringiensis.* When a gypsy moth caterpillar eats leaves that have been sprayed with Bt, it dies in a few days.

EGG MASS COLLECTION

Egg masses are removed from surfaces by scraping them into a bucket. At the end of the collection period, kerosene is added to the container and the egg masses are burned.

NO ACTION

The gypsy moth is allowed to reproduce without human intervention.

Chemical Insecticides Most chemical insecticides are not selective. This means that they are toxic not only to gypsy moths but also to beneficial insects and possibly to other animals.	**Chemical Insecticides** Chemical insecticides are cheap to produce.
Chemical Insecticides Many chemical insecticides are extremely toxic to honeybees and fish.	**Chemical Insecticides** Chemical insecticides are easy to apply—they can be sprayed from airplanes, helicopters, or tractors.
Chemical Insecticides If chemical insecticides are sprayed from an airplane or helicopter on a windy day, insecticide can blow into other areas such as ponds and rivers.	**Chemical Insecticides** Chemical insecticides can be safe and effective when properly applied.
Chemical Insecticides When improperly applied, chemical insecticides may be dangerous to humans.	**Chemical Insecticides** Chemical insecticides kill insects very quickly.
Chemical Insecticides Insect populations can eventually become resistant to a given chemical insecticide. Resistant insects are no longer killed by the insecticide.	**Chemical Insecticides** Certain chemical insecticides have hidden health hazards to people.

Mass Pheromone Trapping

Each pheromone trap can trap up to 75 male moths before it must be replaced with a new trap.

Mass Pheromone Trapping

Mass pheromone trapping is labor intensive. Many hours of work go into folding the traps and attaching them to trees and buildings.

Mass Pheromone Trapping

Since the pheromone is part of the gypsy moth's reproductive biology, gypsy moths do not become resistant to pheromone traps.

Mass Pheromone Trapping

Pheromone traps do not use a toxic chemical to kill the moths. Instead, male moths get caught in the sticky interior of the trap.

Mass Pheromone Trapping

Mass pheromone trapping does not harm other wildlife or humans.

Mass Pheromone Trapping

Pheromone traps must be checked regularly and replaced when they are full of male moths.

Mass Pheromone Trapping

Mass pheromone trapping involves the placement of 1,920 pheromone traps per square mile. Each trap costs approximately $2.50.

Mass Pheromone Trapping

Because the female gypsy moth's pheromone is unique to gypsy moths, pheromone trapping is very selective. Other animals and the environment are not harmed.

Mass Pheromone Trapping

Pheromone traps are often damaged by curious people.

Mass Pheromone Trapping

Pheromone traps are not 100% efficient. They do not catch every male moth that they attract.

Bacillus thuringiensis (Bt)

Bt is a biological insecticide that kills only caterpillars.

Bacillus thuringiensis (Bt)

Bt must be applied to foliage when caterpillars are young. If the timing of the application is incorrect, caterpillars will not be killed.

Bacillus thuringiensis (Bt)

Bt does not accumulate in the food chain.

Bacillus thuringiensis (Bt)

Two applications of Bt, about two weeks apart, are necessary to kill most of the caterpillars in an area.

Bacillus thuringiensis (Bt)

Bt is more difficult to apply than chemical insecticides. It often plugs up spray equipment.

Bacillus thuringiensis (Bt)

Bt has been used successfully in urban and suburban areas and forests.

Bacillus thuringiensis (Bt)

Bt is not toxic to humans, other mammals, birds, fish, and most other insects.

Bacillus thuringiensis (Bt)

Bt will not harm beneficial natural enemies of gypsy moths such as fiery caterpillar hunters and parasitic wasps.

Bacillus thuringiensis (Bt)

Because Bt is commercially produced in large quantities, it is affordable.

Bacillus thuringiensis (Bt)

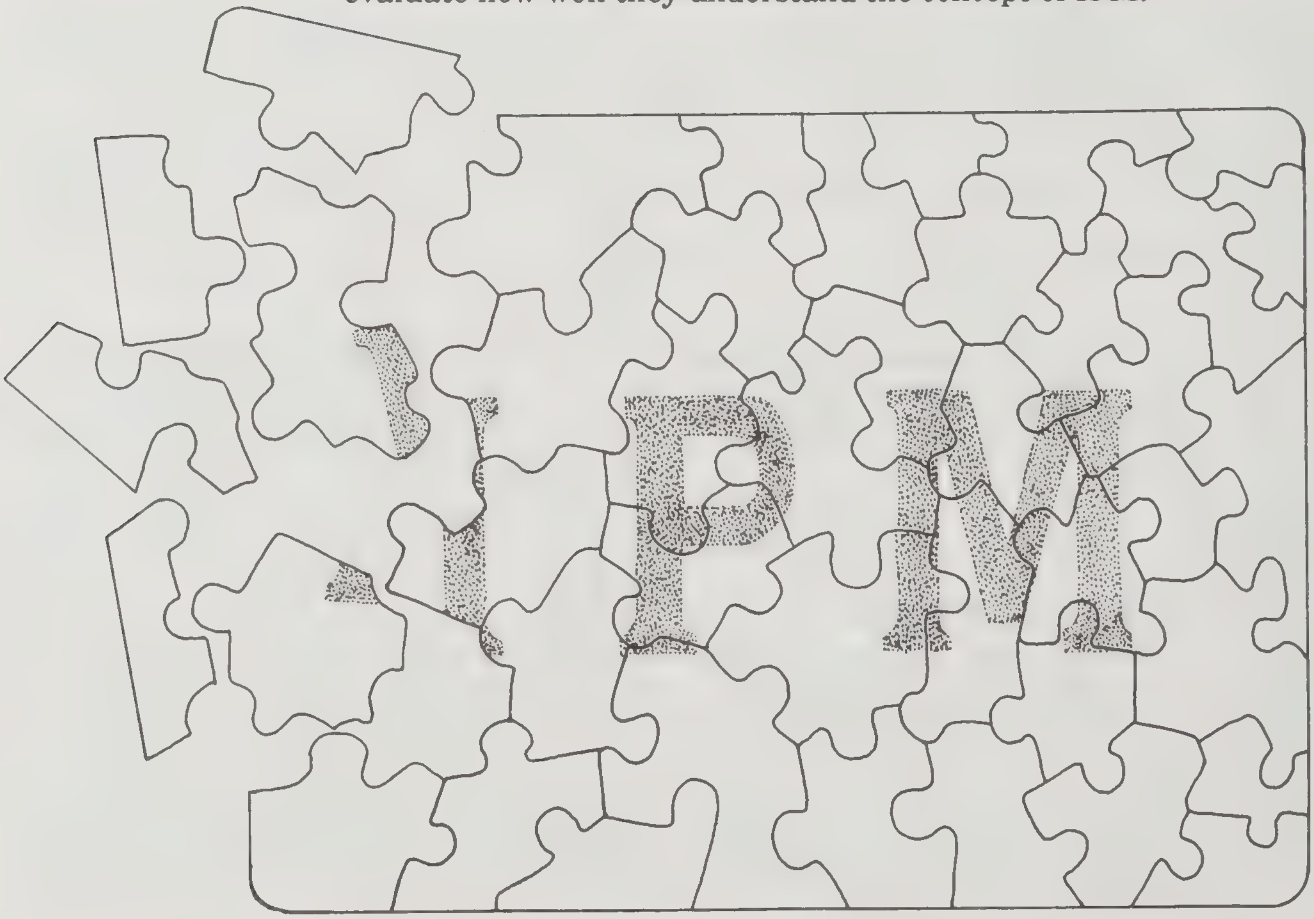
Bt requires several days to kill caterpillars.

Egg Mass Removal Removing gypsy moth egg masses is safe for the environment because it does not damage other organisms.	**Egg Mass Removal** In very small gypsy moth populations that occur in small areas, workers may be able to collect most of the egg masses.
Egg Mass Removal Collecting gypsy moth egg masses does not require complicated skills. Only a good pair of eyes and the ability to correctly identify the egg masses are required.	**Egg Mass Removal** Many gypsy moth egg masses are laid in hard-to-see places and are easily overlooked.
Egg Mass Removal When gypsy moths lay their eggs on branches at the tops of very high trees, these egg masses are often missed. Even when detected, they are difficult to remove.	**Egg Mass Removal** Egg mass removal will help control gypsy moths when the population of moths is small. In large populations, the chance of missing egg masses becomes greater.
Egg Mass Removal Gypsy moth egg mass removal is labor intensive. When people are hired to remove egg masses, labor costs may be very high.	**Egg Mass Removal** Egg mass removal on private property requires that officials get permission from each homeowner.
Egg Mass Removal Large equipment used in tree trimming or power line work may be necessary to remove egg masses laid high in trees.	**Egg Mass Removal** Egg masses must be removed carefully. If any eggs are lost, these will hatch and the gypsy moth problem may continue.

No Action Doing nothing to control gypsy moths may allow the moth's numbers to grow larger each year and become an inconvenience to people.	**No Action** No money is spent on gypsy moth controls.
No Action Ultimately, gypsy moth damage may cost the community its trees.	**No Action** Gyspy moth populations may die out on their own when few preferred species of trees are present.
No Action In an area with many preferred tree species such as oaks, gypsy moth numbers can become large enough to defoliate and damage trees.	**No Action** When winter weather is harsh, gypsy moth populations may die out.
No Action The problems associated with spraying a community with pesticide can be avoided.	**No Action** Gypsy moth populations may spread over a wider area, making them more difficult to control later.
No Action If we ignore gypsy moths, they may go away of their own accord.	**No Action** Communities that have their trees defoliated by gypsy moths experience many problems. These include lack of shade, possible water contamination by gypsy moths, and loss of tourism.

12.B IPM Simulation

OBJECTIVE	to understand the concept of Integrated Pest Management
SKILLS/PROCESSES	application, evaluation, computation
MATERIALS	multiple copies of **IPM Worksheet 1–5** calculator (optional)
PROCEDURE	1. Develop with the class working definitions of the words **integrate** and **manage**; use the dictionary only as a last resort. Building on that base, develop the concept of Integrated Pest Management. Your definition should note that insect populations are managed by using several compatible techniques that avoid damage to plants or animals or that keep that damage at a minimal level. IPM also avoids overreliance on one particular method of control such as insecticides. 2. Distribute copies of **IPM Worksheet 1–5**. When students have completed them, review and expand the definition of IPM. If you prefer, students may work in groups of three or four to complete the worksheets.
EVALUATION	The answers provided by students on the worksheets serve to evaluate how well they understand the concept of IPM.



IPM Worksheet 1 Name:

You are a potato farmer in western Illinois. Last year your crop was very small because your fields were infested with spudmoth caterpillars that eat the leaves of potato plants. You don't like to rely on pesticides to kill pests. Give two reasons:

1.____

2.____

During the winter you would like to develop an Integrated Pest Management program that would incorporate several control methods. Before you can begin, however, you need to understand the life cycle of the spudmoth.

THE PEST

Description of life stages:

Egg: The eggs are small and silvery-green in color. From mid-August to the end of September, they are laid by females in the stems of dead potato plants left in the field after harvest. The eggs spend the winter in the dead stems and are thus protected from the weather.

Larva: The eggs hatch in early May. A light green caterpillar crawls out and immediately begins feeding on potato leaves. It eats and continues to grow by shedding its skin (molting) four times. By early July, it is full-grown (about 1" long) and has three black stripes running down its back. The caterpillars continue to eat, however, until the end of July.

Pupa: At the end of July, the full-grown caterpillar spins a silken cocoon at the base of the potato plant and enters the pupal stage. It remains a pupa for several weeks.

IPM Worksheet 2 Name:

Adult: When the adult emerges in mid-August, it is about 3/4" long and has gray wings with irregular black spots. Males and females look alike except that the male has long feathery antennae to sense the female's pheromone. Soon after emerging from pupae, adults mate, and females lay 10–20 eggs in the dead stems of potato plants left in the field after harvest.

Your study of the life cycle of the spudmoth has led you to select the following control methods to protect your potato crop.

Insecticide control: Bt (*Bacillus thuringiensis*) will be sprayed on the potato foliage after the eggs have hatched. This timing will provide an opportunity for all larvae to eat leaves coated with Bt. Those that consume Bt will stop feeding and die in a short time. You decided to use Bt because it does not kill the parasitic wasps that you will depend upon to help kill the remaining spudmoth larvae.

Biological control: A species of parasitic wasp lays an egg inside nearly mature caterpillars. After the wasp egg hatches, the wasp larva feeds on the internal organs of the caterpillar. When the wasp larva is mature, it chews a hole in the side of the caterpillar and crawls out to pupate. The caterpillar dies soon after the wasp larva pupates. After a week the adult wasp emerges and the life cycle begins again. These wasps are available for mail-order purchase, and you arrange for several thousand to be sent to you in late April. You release the wasps in early May.

Cultural control: Because the spudmoth lays its eggs in potato plant stems left in the field after harvest, you decide to bury dead potato stems and the eggs that were laid in them by plowing the field after harvest in early October. Next spring when the eggs hatch, the caterpillars will be trapped in the soil and will die.

Draw the life stages of the spudmoth on the time line. Separate each stage with a vertical line. Above the time line, use arrows to indicate when each of the three control methods you have chosen should be initiated. Label each arrow with the name of the appropriate control method.

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time line

IPM Worksheet 3

Name: ____________________

To understand how your IPM program will work, answer the following questions.

1. You have an infestation of 250 female spudmoths; each lays 10 eggs in your field.

   How many eggs are in your potato field? ______________________________ A

2. You apply Bt and kill 40% of the newly hatched caterpillars.

   How many caterpillars have you killed? ______________________________ B
   (A× .4)

   How many caterpillars are left in the field? ______________________________ C
   (A – B)

3. The caterpillars continue to grow until they are large enough to attract the attention of the parastic wasps that you released in May. The wasps parasitize 70% of the remaining caterpillars.

   How many caterpillars are parasitized? ______________________________ D
   (C× .7)

   How many caterpillars are now left? ______________________________ E
   (C – D)

4. Of the remaining caterpillars, 50% pupate and survive to become reproductive adults. The other 50% of the pupae die from various causes such as being eaten by birds or drowned in a rainstorm.

   How many pupae are left in the field? ______________________________ F
   (E× .5)

5. One-half (50%) of the emerging moths are female.

   How many female moths are in the field? ______________________________ G
   (F× .5)

6. You harvest your potatoes and sell them to a potato chip company. Each of the female spudmoths in your field lays 10 eggs in dead potato stems.

   How many eggs will be in the potato field? ______________________________ H
   (G×10)

7. It is now time to plow the dead potato stems into the soil. This action buries 90% of the eggs.

   How many caterpillars will die in the spring when the buried eggs hatch? ______________________________ I
   (H × .9)

8. How many spudmoth larvae will survive to eat your next potato crop? ______________________________ J
   (H – I)

9. If you use no control methods against the spudmoth, how many of the caterpillars will pupate and survive to become reproductive adults? Remember, only 50% pupate and survive. ______________________________ K
   (A × .5)

10. One-half of the emerging moths are female.

    How many female moths are in the field? ______________________________ L
    (K × .5)

11. If each of these females lays 10 eggs, how many caterpillars will be in the potato field next year? ______________________________ M
    (L × 10)

12. Compare the number of caterpillars in your field when you used control methods and when you did not.

    with control methods______________________________

    without control methods ______________________________

13. Was your IPM program to control the spudmoth successful? Why?

IPM Worksheet 5 Name:

You are curious to see what effect using only one of your chosen control methods would have on the spudmoth population. You come up with the results shown in the table below. Is using an IPM program more successful than using any single method of control? Why? Which is the most effective method of controlling spudmoth?

starting spudmoth population	caterpillars killed by		eggs killed by plowing	caterpillars alive next year
	Bt	parasite		
2,500	1,000	—	—	7,500
2,500	—	1,750	—	3,750
2,500	—	—	11,250	1,250
2,500	1,000	450	1,008	112

"Yield" is the number of pounds of potatoes produced in your field. When spudmoth larvae feed on the leaves of potato plants, they reduce the number of potatoes the plants produce. Refer to the table above and to the yield information below and explain why the reduction in yield varies, depending upon the control method(s) used.

control method	reduction in yield of potato crop
Bt only	30%
parasites only	50%
plowing only	20%
Bt, parasites, and plowing (IPM)	3%

The information below will help you to understand the effect on yield of the three control methods.

Bt is useful in the caterpillar stage only if caterpillars ingest it. In this scenario, not all caterpillars were killed at the beginning of the season, and those remaining continued to eat leaves throughout the growing season. Parasitic wasps attack only full-grown caterpillars and therefore have no effect on the amount of foliage eaten until later in the growing season. As a result, a substantial reduction in yield occurs. Plowing under dead potato stems in October reduces caterpillar numbers the next growing season.

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Glossary

abdomen the section of an insect's body that contains mating structures as well as reproductive, digestive, and breathing organs

acidic acid-forming, a substance with a pH less than 7

aesthetic value worth related to the beautiful rather than worth based on usefulness or economic value

alkaline base-forming, a substance with a pH greater than 7

annual ring the ring formed each year as a new layer of wood is added to the diameter of the tree trunk

antenna paired structures on the head of an insect used to sense the environment through touch, smell, and hearing (plural: antennae)

anterior the front or head end of an object

appraisal an act of estimating or evaluating

appraiser one who estimates rates, sales price, or status

arthropods animals with segmented bodies, paired jointed appendages, and an external skeleton

bar graph a graph that represents data in the form of bars on the x-axis with the magnitude recorded on the y-axis

Berlese funnel a device used to separate arthropods from leaf litter

bilateral symmetry having two sides that are identical but mirror images of one another

biogeography a branch of science that deals with the geographical distribution of plants and animals

biomagnification the accumulation of substances (usually pesticides or other nondegradable substances) in organisms higher up in the food chain

board foot a unit for measuring lumber equal to the volume of a board 12" × 12" × 1"

carnivore an animal that feeds on other animals

chitin the compound that makes up the cuticle or exoskeleton of arthropods

Coleoptera the order of insects to which beetles belong

community populations of different species of organisms that interact in a given locality or habitat

complete metamorphosis type of metamorphosis in which an insect goes through separate and distinct life forms such as egg, larva, pupa, and adult (cf. **simple metamorphosis**)

compound eye the eye of an insect, composed of many six-sided facets

consumer all organisms that eat or drink; includes all organisms except plants

continuum a continuous succession no part of which can be distinguished from neighboring parts except by arbitrary division (plural: continua)

control trapping using baits or lures to attract and capture a pest species in quantities large enough to lower the size of its population

cross section a section of an object cut so that the interior is viewed as a flat surface, usually at right angles to an axis

data information or facts

data base a grouping of data into a form that is easily usable

decay to break down organic matter gradually into simpler components as a result of bacterial or fungal action; to rot or decompose

decompose to break down into component parts or simpler compounds, to disintegrate or decay

decomposer organisms that break down dead organisms or plant matter into simpler parts

decomposition the process of decomposing

defoliation the stripping of leaves from a plant or tree, especially by insects or through the use of a chemical spray

density the quantity of anything in a specific area; number of objects per unit area

density dependent having influence on individuals that varies with the number of individuals per unit area in the population

density independent having influence on individuals that does not vary with the number of individuals per unit area in the population

detection trapping using baits or lures to attract and capture an animal of a given species to determine if that species inhabits a certain area

detritivores organisms that feed or obtain nutrition from the dead or decaying remains of other organisms

diagonal a line that runs across from corner to corner of a polyhedral figure

diameter the length of a straight line passing through the center of an object and terminating at the periphery

Dictyoptera the insect order that contains the cockroaches and mantids

Diptera the insect order that contains the flies and mosquitoes

dispersal the act of dispersing

disperse to break up or go different ways

dormant having growth, development, or other biological functions suspended

dorsal pertaining to or found on or near the back of an animal or of one of its parts

dose a measure of a substance to be given or taken at one time

ecosystem a series of communities together with the nonliving factors considered as a unit

entomologist a person who studies entomology, the study of insects

exoskeleton the hard external skeleton of arthropods

experimental control a standard of comparison or means of verification

extrapolate to infer from an observed trend

facet a visual unit that makes up the compound eye of an insect

femur the thighbone in humans; the top part of the leg in insects

focus a central or localized area, e.g., the place of origin of an earthquake

food web a diagram that shows the feeding relationships between organisms in a community

gall a swelling on the tissue of a plant caused by the attack of such insects as flies and midges

galleries passages made by insects between the inner wood and the bark of a tree

gene one of the elements of a cell that serves as a transmitter of hereditary characteristics

generation the time it takes for an insect to hatch from an egg, grow to maturity, and reproduce

genetic trait a character that can be passed from parents to offspring

genus a category of classification between family and species; a group of closely related organisms

germinate to sprout, to put forth

grid a network of uniformly spaced horizontal and vertical lines

habitat the particular location where a plant or animal normally lives, e.g., desert, prairie

Hemiptera the insect order that contains the true bugs—squash bugs, bed bugs, and stinkbugs

herbivores organisms that feed entirely on plants

Homoptera the insect order that contains the cicadas, aphids, and scale insects

horizontal parallel to the horizon

humus material formed by the partial decomposition of vegetable or animal matter

Hymenoptera the insect order that contains the flies, bees, and wasps

infest to trouble greatly by numbers or frequency of presence

infestation state of being infested

insecticide any agent that kills insects

instar an insect in any of the forms found between successive molts

integrated pest management the use of several complementary tactics to reduce insect pest populations

intermediate with respect to gypsy moths, the plant species not particularly favored

inventory (noun) an itemized list or catalogue; (verb) to make an itemized record, e.g., to estimate the wildlife of a region

isolated placed alone or apart

Isoptera the insect order that contains the termites

LD_{50} (lethal dose) the amount of a substance that kills 50% of the group of test organisms to which it is administered

larva the immature, wingless form of some insects, often wormlike in form; the form in which certain insects hatch from the egg and in which they remain, with increase in size, until they assume the pupa stage; also called caterpillars, grubs, and maggots (plural: larvae)

leaf litter the debris that covers the forest floor and includes dead and decaying leaves and other plant materials

Lepidoptera the insect order that contains the moths and butterflies

life cycle the sequential changes in the development of an insect, e.g., egg, larva, pupa, adult

life stage any particular portion of the life cycle of an insect, e.g., pupa

locomotion the act of moving from one place to another, progressive movement

maggot the larval stage of flies

mandibles the jawlike appendages that form part of the mouthparts of some insects

metamorphosis change of form or structure

molt (verb) to cast off the old exoskeleton; (noun) the cast-off parts being replaced by new growth

nonpreferred plant species not eaten by the gypsy moth

nonselective insecticide an insecticide that kills a wide range of organisms other than the target species

nontarget organism an organism other than the target species that is killed by a pesticide

nonwoody plants plants that do not have woody tissues, e.g., flowers, herbs, and grasses

nymph the larval stage of development in incomplete or gradual metamorphosis

Odonata the insect order that contains the dragonflies and damselflies

offspring organisms that come from other organisms of the same kind at reproduction

organism any living plant or animal

outbreak an explosion in the number of insects present in a given area

ovipositor a structure found on the abdomen of some female insects that is used for depositing eggs

parasites animals or plants that live in or on the body of another living organism (the host) and contribute nothing to the survival of the host

parasitized the state of being infected with a parasite

persistence the action of staying around or continuing

pest an insect that is considered to be destructive to human health or food resources

pesticide a substance used to kill pests

pheromone a chemical substance produced by an individual organism that serves as a specific stimulus to other individuals of the same species

pheromone trap a collection device that uses a pheromone as the lure; used primarily to collect insects

photosynthesis the process in plants that converts sunlight to plant material

pie chart a circle divided into pie-shaped parts sized to reflect the data

plant stress any natural or human-induced stress that can adversely affect the growth or health of plants

population density the number of organisms of the same kind present in a specified area

posterior the rear end or towards the rear end of an object

predators animals that hunt and kill other organisms for food

preferred with respect to gypsy moths, the plant species upon which they choose to feed

prey an animal used as a food resource by other animals (predators)

producer an organism that produces food or is food for other organisms, e.g., plants are producers for herbivores

pupa the life stage in which reorganization from the larval form to the adult form takes place (plural: pupae)

pupate to become a pupa

rating (noun) a specific value assigned to a relative quantity or condition

reproduction the process of producing offspring

reproductive potential the maximum potential of an organism to produce offspring

resist to withstand the effect of

resistance the state of resisting

resistant to be able to withstand or repel

sample (noun) a part of anything presented for inspection, representative part of a whole; (verb) to assess by examining a representative portion

scientific model a description (often mathematical) used to help visualize (often in a simplified way) a phenomenon that cannot be directly observed

scientific (binomial) nomenclature a worldwide method used to name and identify organisms; all names have two parts and are in Latin

secondary pest an insect that becomes a pest because its natural controls have been removed by an insecticide being used to control another insect

selective pesticide a substance that kills a narrow range of organisms, e.g., Bt is selective for lepidopterous caterpillars

selectivity the quality of being selective

simple metamorphosis metamorphosis in which the change from egg to adult involves a series of gradual changes in the nymphal stage (cf. **complete metamorphosis**)

simulation the act of giving the appearance or effect of

Siphonaptera the order of insects that contains the fleas

species a group of animals or plants that possess one or more distinctive characters in common and can interbreed and produce offspring

species diversity the number of different species in a given area

specificity the condition of being peculiar to a particular group of organisms

spiracles the breathing holes of an insect located on the sides of the thorax and abdomen

spot introductions organisms from another area that are transported and released into a new area where they are not native

stress the state or condition of strain; under adverse conditions

stridulation the process used by crickets to produce sound by rubbing together structures found on the wings

succumb to yield, give way; specifically to give up life

susceptibility the condition of being unresistant; exposed or liable through weakness

synthetic something produced artificially rather that by natural growth

systemic pesticide a substance absorbed into the blood or sap of an organism that makes it toxic to pests that feed on it

target pest the organism that is the object of control practices such as pesticides

thorax the middle body section of the insect and the location of the locomotor appendages, e.g., legs and often one or two pairs of wings

tibia the shinbone in humans; the part of the leg attached to the femur in insects

top consumer the top carnivore or consumer in a food web or trophic pyramid

toxicity the relative degree of being poisonous

toxin a substance poisonous to living organisms

trophic having to do with nutrition, as in the feeding relationships in a food web or food (trophic) pyramid

tympanum the hearing organ found on the tibia of the cricket

unit (of measurement) a determinate quantity (length, time, heat, etc.) adopted as a standard (mm, second, degree, etc.)

vegetarian an individual who eats only vegetables and no animal products

ventral in animals, pertaining to or situated on or toward the bottom surface of the body

vertebrates organisms that have internal skeletons with a backbone or spinal column

vertical perpendicular to the plane of the horizon

woody plants plants that have or contain wood or woody fiber, e.g., trees and bushes

Insect Sweep Net

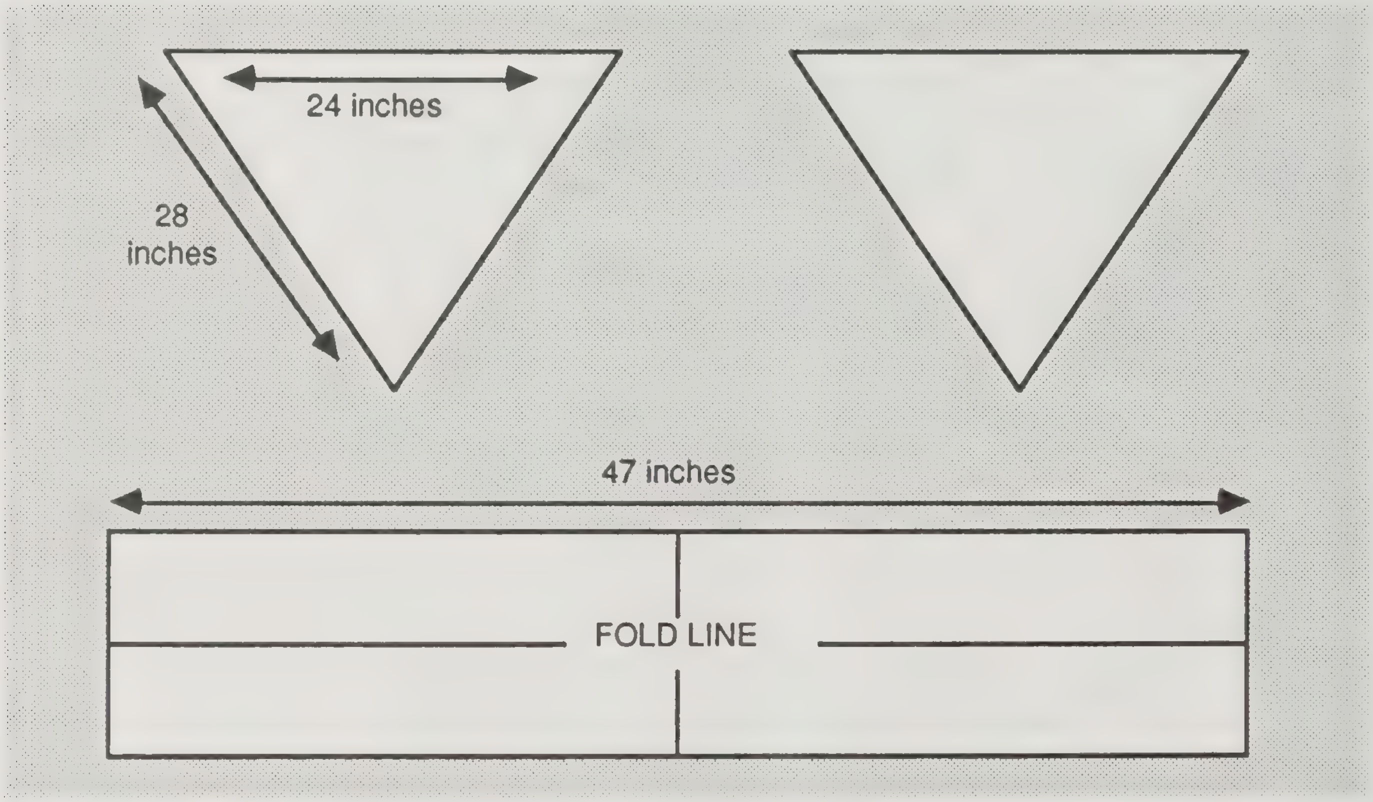
Insect sweep nets can be purchased commercially, but they also can be made at home.

MATERIALS

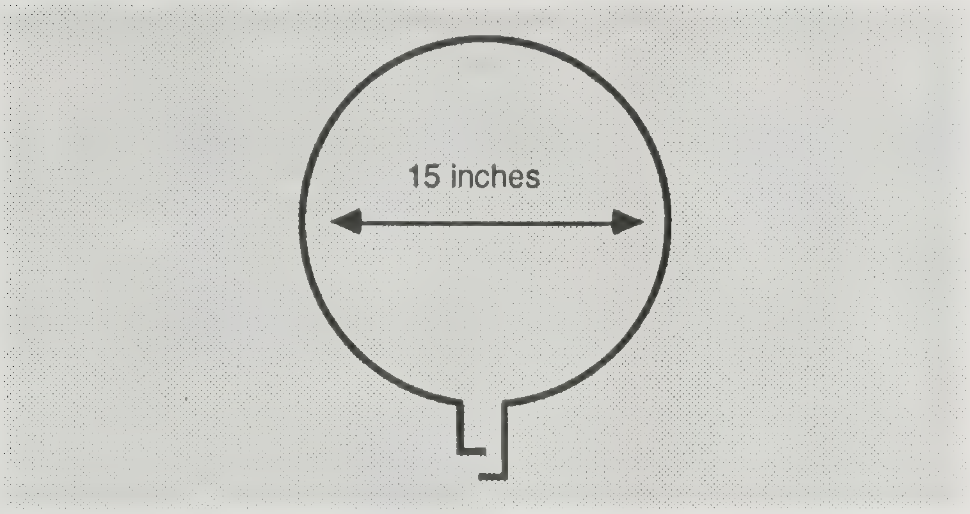
handle: a large wooden dowel or discarded broom handle
(approximately 4 feet long for an adult)
sturdy wire: (no. 6 to no. 8) 4' 6" long, which can be bent
into a rigid circle of about 15" in diameter
muslin
fine wire or hose clamp to secure net to handle

CONSTRUCTION

Net. Cut two muslin triangles with the dimensions shown below. Sew the triangles together along the 28-inch edges. Fold a band as shown below and set it around the top of the net. Leave a gap of about 2" between the ends of the band for inserting the wire hoop. Allow 1/2" for all seams.



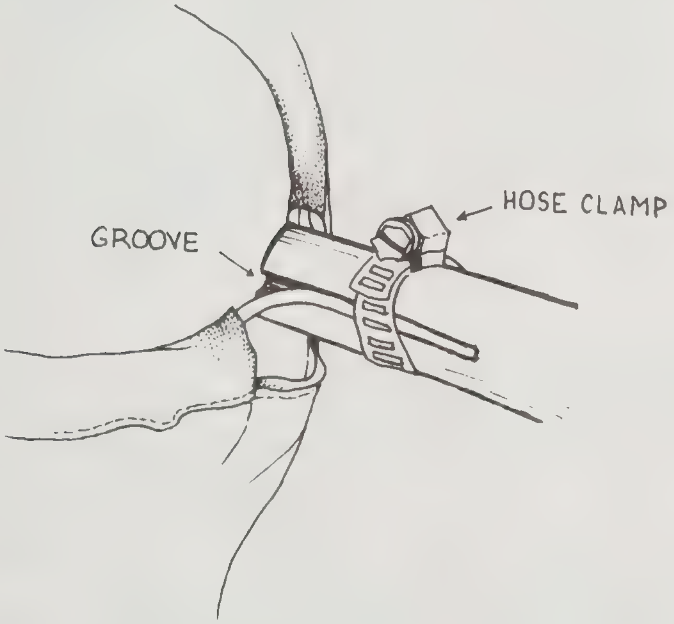
Hoop. Shape the hoop as indicated below, making one stem 1/2" longer than the other.



Handle. On opposite sides of the handle, score grooves for the wire stems.

ASSEMBLY

Thread hoop into the handle grooves and fasten securely with a hose clamp or with fine wire wrapped around the handle.



Killing Jar

MATERIALS

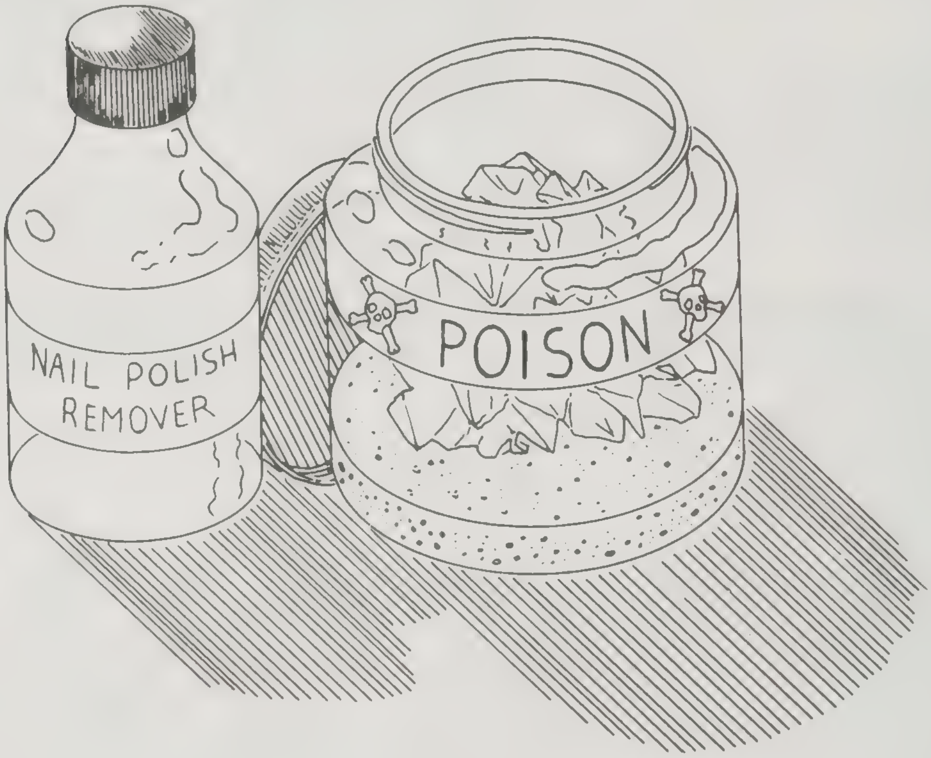
- clean glass jar with screw lid, e.g., a 16-ounce peanut butter jar
- plaster of paris
- nail polish remover
- tissue (kleenex or wrapping tissue)
- masking tape

CONSTRUCTION

1. Make sure the jar is clean and dry.
2. Pour about 1 inch of plaster of paris into the jar. Allow it to set.
3. Add nailpolish remover to the jar until the plaster of paris appears saturated. No pools of polish remover should remain on the surface.
4. Place several crumpled pieces of tissue paper into the jar to keep the insect from getting damaged.
5. Put a piece of masking tape around the jar and label it **POISON.** If the jar is dropped, the tape will keep it from shattering.

USE

Keep the lid tightly closed whenever possible. Do not put moths and butterflies in a jar with other insects because they shed scales from their wings and bodies and contaminate other specimens.



Spreading Boards

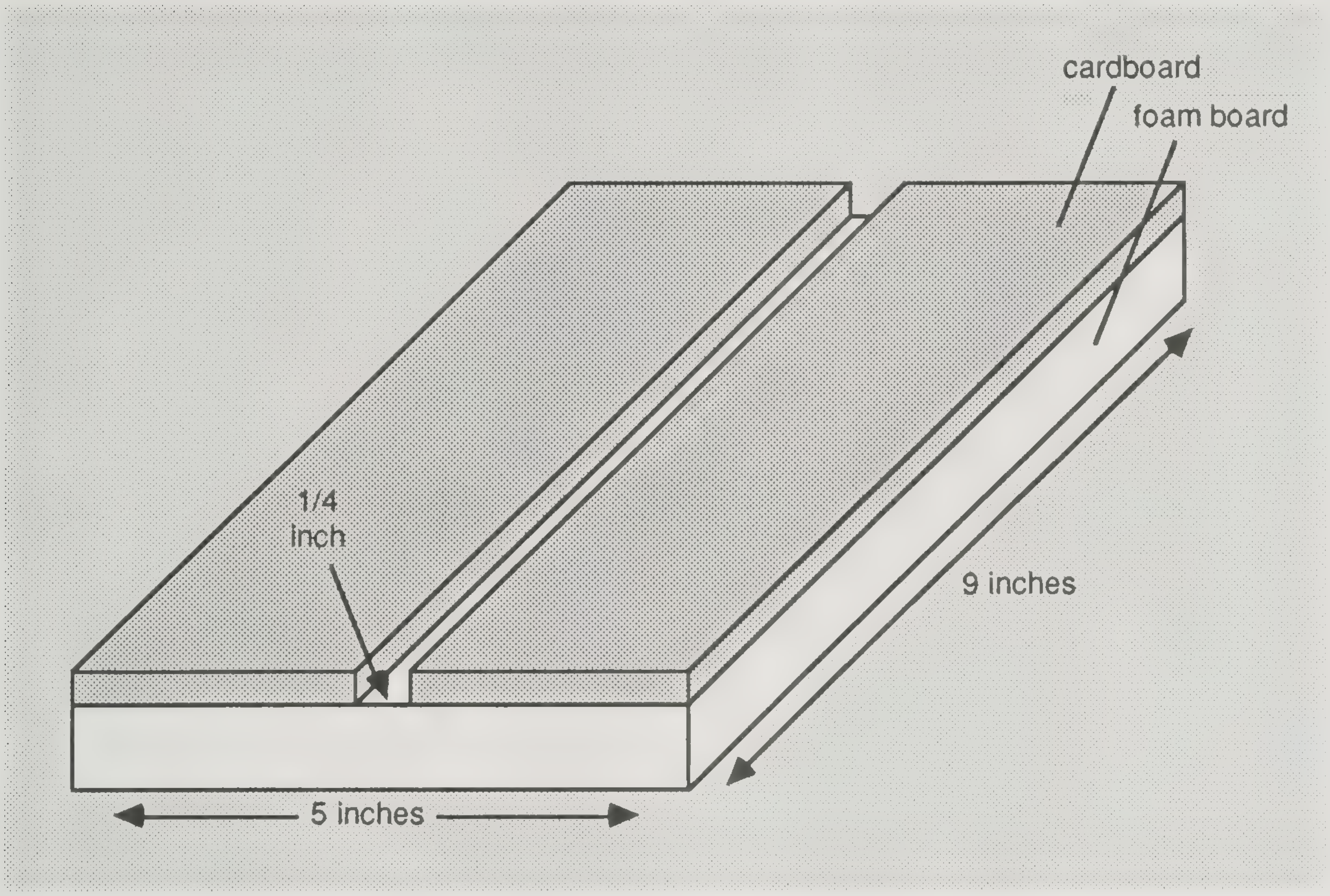
Spreading boards are used to spread and dry the wings of moths and butterflies in a flat position.

MATERIALS

thick, corrugated cardboard
foam board (available at art stores) approximately 3/4" thick; if only thinner dimensions are available, build up adequate thickness by glueing together pieces 1/2"and 1/4" thick
razor blade or x-acto knife

CONSTRUCTION

Cut a piece of foam board 5" × 9". Cut a piece of cardboard 4–3/4" × 9"; cut this piece in half lengthwise. Place these cut halves on top of the 5" × 9" base. Separate the cut pieces of cardboard by 1/4" and glue the two pieces down to the foam base in that position.



USE

Directions for spreading moths and butterflies are found in the references below.

Borror, D.J., D.M. Delong, and C.A. Triplehorn. 1976. Collecting, Preserving, and Studying Insects. Pages 725–766 *in* D.J. Borror et al., An Introduction to the Study of Insects. 4th ed. Holt, Rinehart & Winston, New York.

Ross, H.H. 1966. How to Collect and Preserve Insects. Illinois Natural History Circular 39. [Although copies of this publication are no longer available from the Survey, Circular 39 may be obtained from the Library of the University of Illinois and from other libraries throughout the state.]

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